MOTOR CARS

A. J. WALLIS-TAYLER

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MOTOR CARS

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MOTOR CARS

OR

POWER-CARRIAGES FOR COMMON ROADS

BY

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PREFACE.

THE extraordinary restrictions against travelling by mechanical means over the roads of this country, which have existed for so long a time, have now been partly removed by the passing of the Locomotives on Highways Act of 1896. Those restrictions have doubtless been the means of inflicting very great injury upon the trade of the country. This, indeed, must be only too evident, when it is considered that not merely have large and struggling classes of the community been debarred for years from the advantages they would have derived from this method of transport, but English engineers, unable to carry out even the needful experiments, have been forced to stand idly by, instead of occupying themselves in developing and perfecting the power-propelled road carriage, and so establishing a great industry.

At the present moment, it seems to the author that a satisfactory power-propelled carriage for common roads has yet to be designed. All that past experi-

ments in this country, and the more recent experiments abroad, have succeeded in producing are vehicles which serve to show the practicability of devising carriages which may be driven by mechanical power, even with great facility, upon common roads.

Although, however, the motor carriage of the future is not with us yet, the present would seem to be an opportune time to place before the public a concise account of the various systems of propulsion which have been adopted for the vehicles now commonly designated motor cars or horseless carriages, and of the principal types of such vehicles which have been constructed to the present date. In the execution of this task the author has sedulously avoided entering discursively upon the theories of the various motors, subjects with which engineers should be already fully conversant, and with which other persons are not greatly concerned, and which, moreover, are already amply dealt with in many able treatises.

The author begs to acknowledge his indebtedness to the columns of *The Engineer* and of *Engineering* for much of the information which appears in a condensed form in the following pages, as also for some of the illustrations by which the text is elucidated. The full descriptions that have been given in these journals, especially during the past year, of motor cars possessing features worthy of consideration, must have rendered their perusal a task of pleasure and

profit to the engineer, and one peculiarly pleasing to those interested in the new industry now being developed; whilst the wholesome warnings against the inflated schemes of the company-monger—who is always to the fore on such occasions as the present—have doubtless already saved, and should hereafter save, the pockets of many. Work such as that ranks as a public service.

It should be added that much useful information upon the subject of this volume may also be derived from the pages of other technical journals, and especially those entirely devoted to the subject of motor cars, some of which latter are in every way admirably conducted.

A. J. WALLIS-TAYLER.

323 HIGH HOLBORN,
LONDON, W.C., *April* 1897.

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OR,

POWER-CARRIAGES FOR COMMON ROADS.

CHAPTER I.

INTRODUCTION.

THE embargo under which motor cars or horseless carriages have so long rested in this country having been at length partially raised, we may reasonably expect in the near future to possess really practical and serviceable machines.

At present, however, it must be acknowledged that the successes attained with the few motor cars designed in this country in the past, and the numerous ones more recently constructed abroad, have been only sufficient to show the feasibility of this kind of locomotion, and to encourage further attempts at their perfection, as all the cars that have been as yet built,

and are now on the market, are more or less unsatisfactory in various particulars.

Under such circumstances, it might be asked whether an account of the comparatively imperfect motor cars that have been designed up to date would be of any great utility, and whether books upon the subject are not at this stage of the art premature. The author thinks not, for the following reasons:—Firstly, that the evolution of a perfect machine must of necessity be a somewhat slow and gradual process, taking many years, and meantime information upon what has been already effected, condensed, and presented to the reader in a handy form, will be not unuseful; and secondly, that in the future the existing comparatively crude examples will be of interest as forming an important link in the history of what will no doubt have then become an important industry.

As soon as a demand for motor cars arises, we may expect to find the large and old-established firms of engineers, gradually but surely developing, from the more or less imperfect machines now extant, power-propelled vehicles of all descriptions that will meet in a satisfactory manner the requirements for different duties. But it is to these large firms, and to the eminent engineers connected with them, that we must look for such improvements, and not to the charlatans who will doubtless utilise the occasion to the utmost, and succeed in fleecing not a few of the unwary.

In connection with motor cars or road locomotives there exist no master patents—in fact, very few patents at all that are worth the paper they are printed upon; and it would be well for those who feel tempted to invest in any of the plausible schemes that will be put

before them to bear this in mind, as also the fact that, even under the most favourable circumstances possible, the general introduction of these vehicles, and the supersession of the horse, could only be the result of many years. Remember it took a long lifetime to establish the railway.

In *Engineering* for the 29th of May of this year (1896) there appeared an article upon "Company Promotion and Horseless Carriages," every line of which is pregnant with meaning, and teeming with words of advice to those who are likely to fall an easy prey to the human vultures who thrive exceedingly in this country during the present state of the law relating to company promotion. Space does not admit of here reproducing the article above referred to *in extenso*, but the following extract, which contains the pith of that warning, the author would fain give, and that not merely expressed in language stronger and clearer than that in which he might possibly be able to put it, but also bearing the weight which should attach itself to the opinion of one of the leading technical journals of the country:—

"The horseless carriage boom is going to afford a rich field for the operations of the professional company promoter—a veritable Tom Tiddler's ground for those ingenious but not over-scrupulous persons who exist and grow rich mostly by virtue of the credulity and greed of small speculators.

"These booms, rushes, speculations, and fevers are the curses of honest industry. The haste to get rich kills useful work. Perhaps no industry suffers more from this than the engineering industry—inventor, capitalist, and workman alike being constantly made victims. Indeed, the whole

country is poorer for every over-blown scheme floated, and which, in the inevitable course of events, collapses, if only from the fact that honest, sober ventures are thereby discredited, and enterprise is thus checked.

"We are believers in the further extension of mechanical traction, but it will not come with the rush that many anticipate. Changes of this kind are of necessity gradual. The 'passing of the horse,' of which we hear so much, is an absurdity. Those who are now trying to tempt the sanguine small investor point to the railway and the bicycle as examples of what will take place in regard to horseless carriages, forgetting, or hoping those they address will forget, that it took the best years of George Stephenson's life to establish the railway. There was a wide gap even between Stockton and Darlington and Liverpool and Manchester; whilst to carry the history of steam locomotion to a period when many of the great lines were paying reasonable interest on the capital expended brings us well within the memory of men who would scorn to describe themselves as 'elderly.' That is a point intending plungers on horseless carriage speculations would do well to remember. As for the cycle business, it took twenty years to establish it on anything like an important basis; and even now, with the woman's mania—which will go out like a snuff when fashion changes—in full swing, the establishments which are paying big dividends are those which have grown up bit by bit from small beginnings. It is by accretion that prosperous businesses are made, not by prospectuses.

"The credulity of the investing public seems inexhaustible. No bait is too coarse, no lure too ill concealed, to attract victims. Often a simple addition sum would show the futility of the expectations set forth. A little investigation would reveal how certain is the gain of the promoters, how improbable that of the investor. We turn to the columns of the press and occasionally find whole sheets

occupied by mammoth advertisements of the formation of a company. They are numerous and costly enough to be a serious handicap of any legitimate business likely to be done, and are penned in the worst possible taste, with a coarse attempt to glorify an individual taking a prominent part in the business. One would think their tone would be sufficient to alarm any educated person; but presumably it is not so, and doubtless the experienced individuals who have the conduct of such affairs know best how to appeal to their public. Perhaps it is that parsons, country doctors, naval and military officers, and the widows of all these, who form the bulk of the company-monger's clients, think that vulgar self-assertion and business shrewdness must always go hand in hand."

In treating of motor cars or power-propelled carriages in the following pages, it is not proposed to devote any special attention to the design pure and simple of the vehicles, which latter will, of course, be largely governed both by individual tastes and also by the special requirements of different districts and countries. The subject, therefore, which will be as fully treated as the very limited space at command in a little book of this description, which must necessarily be of a somewhat elementary character, will admit of, will be the various kinds of motive power employed for propulsion, and the mode of application to the vehicles to be driven. With this object in view, the mechanically propelled vehicles will be classified and successively treated of in the following pages in accordance with the type of motor employed under the following headings:—Steam-carriages; petroleum and other internal combustion engine carriages; electric motor driven carriages; com-

pressed air engine driven carriages; and carriages driven by power stored in compressed carbonic acid or carbon dioxide, compressed springs, &c.

Moreover, it is not purposed to more than touch upon the theoretical side of the subject, and indeed it is obvious that were this aspect to be gone into with any degree of completeness,—and it would be otherwise idle to attempt it,—it would demand in combination with that under consideration an extended discussion of the sciences of thermo-dynamics, chemistry, and electricity, not to mention that of the mechanical questions which would especially apply to the several sources of energy in use. Those readers, therefore, who are not conversant with the above, and who are desirous of entering into the theoretical part of the question, we must refer for information to the many able treatises that have been written upon the above sciences.

Before proceeding to deal with the subject in the manner intimated, it will be both interesting and instructive to give, first, a copy of the report made by L. L. Summers and J. Lundie, two well-known American engineers, who undertook a series of tests on behalf of the *Times Herald* of Chicago with the object of ascertaining, in view of the race organised by that paper, how far motor cars or power-propelled vehicles were capable of performing the work of those moved by animal traction; and, second, to offer a few remarks upon wheels, and to give the main results of some interesting experiments lately carried out by Professor H. S. Hele-Shaw, M.I.C.E., on the resistance of steel, solid rubber, and pneumatic tyres.

As regards the first mentioned, the report was as follows:—

"The Committee first endeavoured to choose a series of experiments which would enable comparison to be made between mechanical and animal traction. The main point was to prove that auto-cars could do the same work as other ordinary vehicles. Consequently the horse was chosen as the unit for this comparison; and in order to facilitate this, it was thought advisable to give a short account of the first experiments which were made with the object of determining the power exerted by a horse.

The Horse-Power Unit.

"When the steam-engine first came into use it was found necessary to compare the rate of work it could do with the rate of work done by a horse, in order that the buyer might specify the power he required by means of some known unit.

"James Watt was the first to ascertain with some accuracy the average power of a horse. He found that a weight of 150 lbs. could be raised by a horse at the rate of 220 feet per minute, which corresponds, consequently, to 33,000 foot-pounds per minute as the power which a horse could exert. According to Watt, the horse could exert this power during eight hours a day.

"Later experiments have shown that this estimate was exaggerated, and that an average horse scarcely exerted more than 22,000 foot-pounds per minute during eight hours, though this amount would evidently be greater if the horse worked during a shorter period.

"The following Table, taken from Trautwine, and based upon the above, gives some figures on the subject :—

Speed of Horse in Miles per Hour.	Traction in lbs.	Speed of Horse in Miles per Hour.	Traction in lbs.
0.75	333.3	2.25	111.1
1.00	250	2.50	100
1.25	200	2.75	90.9
1.50	166.6	3.00	83.3
1.75	142.8	3.50	71.4
2.00	125	4.00	62.5

"It is evident that not only can a horse exert a considerable tractive effort for starting purposes, but he can also vary his power considerably on the road, so that he is very suitable for general traction. The maximum power of a horse has not yet been absolutely determined, but it certainly varies considerably with his weight, with the length of his stride, and with the nature of the ground he travels over. We do not believe that a horse can ever exert a greater pull than 400 lbs. To compare an auto-car with a carriage drawn by a horse, then, it is necessary to calculate the power exerted by the motor on the rim of the driving wheels, and also the circumferential velocity of the latter. The mechanical horse-power of the auto-car in question will be found by dividing the product of these two factors by 33,000 foot-pounds.

"The cost per hour for every horse-power exerted on the rim of the driving wheels can then be reduced by measuring the consumption of the motor during each test. Where it has been possible to do so, the amount of power lost between the motor and the rim of the driving wheels, and the effect of the different methods of regulation upon the fuel consumption, have been determined.

Fuel Consumption Tests.

"These tests bore upon the consumption of the motor for the various loads imposed by practice.

"In order that all the motors should be tried under the same conditions, gasoline, having a density of 0.658, at an estimated cost of 1d. per lb., was supplied to them from the same tank.

"The cost of a kilowatt-hour was calculated on the basis of an average accumulator efficiency of 75 per cent.

Maximum Pull Exerted by Auto-Cars.

"It was considered advisable to determine this, in order to be better able to compare the auto-car with the horse. The cars tried were all built to exert a comparatively light pull at great speed, and not a heavy pull at low speed.

"The maximum pull exerted was found by opposing a resistance to the wheels till the motor stopped.

"The Duryea car, for instance, only exerted a pull of 187 lbs., whereas we have seen that one horse could pull 400 lbs. During none of these tests, however, could the driving wheels be made to skid on the

ground, so it is possible that the tractive force could have been very much increased without skidding by using reducing gearing.

"When belting was employed on the test cars for transmitting the power, it was found that the latter reached its maximum value just before the belts slipped on the pulleys. Mr Macy's car could not be tested thoroughly on account of the defective condition of the belting employed. The Lewis auto-cycle broke its driving chain when the maximum pull was being measured. As to the electric motors, the maximum pull obtainable was limited only by the heating effect of the strong current employed.

"A great difference in the consumption of the several cars on trial is shown in the Tables.* This is due solely to the nature of motor employed. Nearly all the single cycle motors burn a great deal of fuel, caused generally by the improper combustion of the gases. This is the case with the Lewis and the Haynes cars. Whilst these cars were being tested, the exhaust gas was so charged with unconsumed carbon that it was found necessary to have a special exhaust pipe and fume blast to convey the fumes from the testing-room.

"It must be acknowledged, however, that single cycle motors work much more regularly than the others.

"It is a pity that the igniting apparatus on the Duryea car should have got out of order, putting a stop to further experiments. All those interested in the construction of gas motors know that the cycle

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* See Tables on pages 14, 15, and 16.

obtained is less economical than that made by steam. The average efficiency is still lower when the gas motors are used for traction, for the following reasons :—

" 1. Because work is sacrificed in driving the machinery.

" 2. Because a 4 horse-power motor, for example, seldom works at its normal speed and power, so that it cannot have a high efficiency.

" This is why the fuel consumption of auto-cars is comparatively high.

" With regard to the Benz motor, attempts were made to simplify the transmission gear by having only two ranges of speed. Speeds between these two extremes were obtained by regulating the amount of carburetted mixture supplied, but a glance at the Tables* shows at once that this ease of control and simplification of mechanism is more than neutralised by the very large amount of fuel which the motor consumes when it is not working at its normal speed.

" Evidently the useful horse-power exerted on the rim of the driving wheels, when the motor is working under the best conditions of speed and power, costs about one-fourth of its cost when working under the most unfavourable conditions.

" In such cars as the Duryea car, where the speed of the motor is always constant, the efficiency is in proportion to the amount of work done, so that an auto-car may often climb a bank at the same speed as on the level without consuming more fuel, for the very reason that the extra power required is com-

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* See Tables on pages 14, 15, and 16.

pensated by a better efficiency. The position of the motor on the car and the method of transmission employed greatly influence the amount of vibration on the car.

"When the motor is mounted at right angles to the driving axle, as on the Benz car, the vibration is rather strong, especially at starting. Messrs Haynes & Apperson's car is fitted with a motor having two cylinders arranged upon opposite sides of the driving shaft, and this arrangement gives less vibration.

Electric Cars.

"The exact efficiency of an electric auto-car is somewhat difficult to determine. The storage battery efficiency varies with the discharge rate, which again depends upon the work done. The cost of electric power varies from town to town, and this fact must be taken into consideration when calculating the cost of electric traction.

"The life of the accumulators also will depend upon the kind of work which the car is made to do.

Single and Double Motors.

"Mr Sturges and Messrs Morris & Salom's two cars enabled an interesting comparison to be made. Both cars employ Lundell motors, but whilst Mr Salom has two motors, one for each driving wheel, Mr Sturges only employs a single 3 horse-power motor working on a differential shaft.

"The motor efficiency in these two cars is practically the same, but of course the transmission gear is heavier with two separate motors than with one.

We do not think the advantage of being able to couple up the motors in series or in parallel quite justifies the employment of two motors, and the only real advantage of this arrangement is to enable the driving wheels to run independently of one another when turning round corners, instead of having to employ differential gearing to effect this."

There can be no doubt but that the practical success or otherwise of motor cars or power-propelled vehicles will depend to a great extent upon the wheels, which latter will have to be so constructed as to be capable of withstanding the very heavy strains to which they will naturally be subjected, especially on the inferior roads so common in this country. This portion of their anatomy will be to some extent gone into when dealing with the different types of cars. As, however, it is not unlikely that pneumatic tyres may play as important a part in connection with motor-car wheels as they have already done in the case of those of cycles, the result of the before-mentioned recent experiments of Professor H. S. Hele-Shaw * will be of interest, and that the more so as they confirm those already obtained by others.

Three similar vehicles—whose exact weight was not known—were employed for the purpose in question. The tests were made in the show-room of Messrs Lawton & Co.'s works, Hardman Street, and in each case the pull required to start the vehicle was measured by a spring balance. The mean effort

* Lecture on "Pneumatic Tyres for Motor Carriages," by Professor H. S. Hele-Shaw, before the Liverpool Branch of the Self-Propelled Traffic Association.

Power and Duty Tests of Auto-Cars.

Electric Cars.

Car.	Number of Run.	Pull exerted in Pounds.	Horse-power exerted at Rim of Wheel.	Total Horse-power developed in Motor.	Mechanical Efficiency.	Electrical Input in Horse-power.	Kilowatts supplied by Accumulators per Horse-power at Rim of Wheel.	Foot-pounds at Rim of Wheel per Kilowatt-hour.	Cost per Horse-power-hour at Rim of Wheel (Pence).	Maximum Pull exerted (Pounds).	Horse-power consumed in Mechanism.	Speed in Feet per Minute.	Input. Volts.	Input. Amp.	Heating of Bearings.
Morris & Salom	1	25.5	0.78	1.12	0.70	1.36	1.74	1,138,000	8.00	—	0.34	1,025	97	10.5	
Lundell Motor	2	29	1.78	2.46	0.72	2.90	1.63	1,215,000	7.49	—	0.68	2,015	96	22.5	
Sturges Electric Moto-Cycle Co.	1	41	0.41	0.62	0.66	0.99	2.42	818,000	11.13	121	0.21	370	35	21	
Lundell Motor	2	42	1.14	1.53	0.74	1.94	1.70	1,165,000	7.82		0.39	892	69	11	

Power and Duty Tests of Auto-Cars.

Car.	Number of Run.	Pull exerted in Pounds.	Horse-power exerted at Rim of Wheel.	Total Horse-power developed in Cylinder.	Mechanical Efficiency.	Gasoline, Pounds consumed per Hour.	Gasoline, Pounds consumed per Horse-power-hour at Rim of Wheel.	Foot-pounds at Rim of Wheel per Pound of Gasoline.	Cost per Horse-power-hour at Rim of Wheel (Pence).	Maximum Pull exerted (pounds).	Horse-power consumed in Mechanism.	Speed in Feet per Minute.	Remarks.
De la Vergne	1	37	0.70	1.41	0.50	3.24	4.63	428,000	4.63	162	0.71	619	
	2	51.8	1.57	2.97	0.53	4.45	2.83	700,000	2.83		1.40	1,000	
Duryea (Springfield)	1	83.8	1.10	1.69	0.65	4.01	3.64	545,000	3.68	187	0.59	432	Trouble with igniter.
	2	88.5	1.16	1.75	0.65	3.78	3.24	623,000	3.24		0.59	434	
Haynes & Apperson	1	23.1	0.26	0.87	0.30	5.78	21.8	91,000	21.8	119	0.61	376	Two cylinders in use, one supplying power.
	2	39.3	0.95	2.23	0.43	5.75	6.04	327,000	6.04		1.28	796	
Lewis (Chicago)	1	49.9	0.53	1.06	0.50	3.29	6.20	319,000	6.20	109	0.53	353	Chain broke.
	2	17	0.25	0.90	0.28	3.28	12.8	155,000	12.8		0.65	491	
Macy (New York)	1	52.1	0.83	2.31	0.36	3.22	3.90	515,000	3.90	103.7	1.48	521	Belt slipped.
	2	87.2	2.50	5.18	0.48	4.90	1.96	1,010,000	1.96		2.68	945	
Mueller & Sons (Mueller Benz Motor)	1	92.1	1.18	1.79	0.66	3.50	2.96	669,000	2.96	132.4	0.61	423	
	2	42.3	0.69	1.46	0.47	3.87	5.6	354,000	5.6		0.77	540	
	3	38.6	0.66	1.47	0.45	3.77	5.71	347,000	5.71		0.81	564	
	4	73.4	2.18	3.75	0.58	3.40	1.57	1,268,000	1.57		1.57	984	
	5	34.7	1.23	3.09	0.40	4.15	3.37	588,000	3.37		1.86	1,168	

DETAILS AND DIMENSIONS OF MOTORS.

CAR.	Weight on Driving Wheels.	Weight on Steering Wheels.	Total Weight.	Wheel Base.	Distance apart of Driving Wheels.	Distance apart of Steering Wheels.	Radius of Driving Wheels.	Radius of Steering Wheels.	Position of Driving Wheels.	Nature of Tyre employed.	Fuel used.	Number of Cylinders.	Bore of Cylinders.	Stroke of Piston.	Nature of Bearing.
	lbs.	lbs.	lbs.	ins.	ins.	ins.	ins.	ins.					ins.	ins.	
De la Vergne (New York)	1,250	430	1,680	66.7	—	—	23.7	18.2	Rear	Solid rubber	Gasoline	1	5.12	6.62	Roller.
Duryea (Springfield)	729	479	1,208	57.5	55	53.7	22.8	18.7	,,	Pneumatic	,,	2	4	4.5	—
Haynes & Apperson	829	421	1,250	54	55.2	55.5	17.8	17.9	,,	,,	,,	2	4	4	Ball.
Lewis (Chicago)	900	780	1,680	56	46.6	46.5	22.9	16.7	,,	Solid rubber	,,	1	5	5	Roller.
Macy (New York	1,440	385	1,825	67	52	52	23.8	17.9	,,	,,	,,	1	5	7	,,
Morris & Salom	1,260	390	1,650	49	44.2	36.1	19.8	14.2	Front	Pneumatic	Accumulators	Motors	—	—	Ball.
Mueller .	1,251	385	1,636	73	50.2	47.8	24	18.4	Rear	Solid rubber	Gasoline	1	5.5	6.25	Roller.
Sturges . .	2,085	1,450	3,535	65	57	57	25.1	23.2	,,	,,	Accumulators	1 Motor	—	—	Plain.

required was estimated by the average reading of the balance, whilst the vehicle was pulled at a uniform speed over a track about 6 feet long. The results were as follows:—

The first track was across the floor, the second with obstructions 1 inch apart, the third with an interval of 2 inches, and the fourth with 3 inches between the blocks.

Track.	Steel Tyre.		Solid Rubber Tyre.		Pneumatic Tyre.	
	Starting Effort.	Mean Pull.	Starting Effort.	Mean Pull.	Starting Effort.	Mean Pull.
Floor . .	31.2	21.4	24	17	30.25	22
Second . .	37.4	22	27.4	18.7	29	22.25
Third . .	43.8	21.2	36.8	19.8	30.75	23.25
Fourth . .	?	21	36.8	20.2	40.5	25.5

The results obtained by these experiments came out, it will be seen, exactly as theory would lead to expect, and it is of course obvious, and has never been disputed, that if the only resistance to be encountered was rolling, a hard-tyred wheel would give better results than a soft one. The advantages gained by the use of pneumatic or air tyres are due to the fact that upon a wheel fitted with the latter encountering a small obstacle, such as a stone or the like, the latter sinks into it, and the wheel is not forced to rise to the same extent as would be the case with a hard tyre, and consequently the loss of energy will not be

so great. This benefit possessed by soft yielding tyres is, moreover, only apparent when rolling at a certain degree of speed, and the greater the acceleration of speed the greater will be the advantage derivable from the fitting of soft tyres to the wheels of a vehicle. Indeed, at very slow speeds the resistance to soft tyres has been found to be actually greater than that to hard tyres.

The results of Professor Hele-Shaw's tests, which confirm those lately carried out by M. Michilin, must agree with the practical experience of all those who have carefully studied the behaviour of pneumatic tyres on cycles, upon which class of vehicle, especially the bicycle or dicycle, the benefit of soft tyres is of course more readily apparent, inasmuch as they are ordinarily propelled at a considerable velocity. In addition, there are of course the following well-known and not inconsiderable advantages derived from the employment of soft tyres, viz., practical immunity from jolting and vibration, and consequently from the injury to the parts of the vehicle therefrom, steadiness of motion, noiselessness, non-injury to the surface passed over, and last, but by no means least, ease to the rider, upon whom the jolting experienced in passing over rough roads or pavements with hard tyres has a very exhausting effect.

The matter is briefly summed up by Professor Hele-Shaw as follows:—Soft tyres do involve more friction than hard ones, but the loss of power on an ordinary hard road is due in a much greater degree to the loss from concussion than to actual friction, and that the order in which the loss of power takes place in the cases respectively of the pneumatic, rubber,

and iron tyres, is directly in the order of the hardness of the tyre.

A series of somewhat crude experiments recently carried out with cycles by the author, which he hopes to find time shortly to supplement by ones more extended and carefully conducted, gave the following results :—Single tube pneumatic tyres (Boothroyd and National) inflated to about 30 lbs. per square inch, carrying a load of 200 lbs., and pulled at an uniform speed of 44 feet per minute on a level surface, developed .08 per cent. more rolling friction than solid indiarubber tyres similarly loaded and moved at a like speed. Upon increasing the speed, however, to 440 feet per minute, the rolling friction was practically the same in both cases, and upon interposing obstructions, consisting of pieces of wood about the size of ordinary wooden penholder handles secured at regular intervals of 4 inches apart, the rolling friction of the pneumatic tyres was found to be reduced to .1 per cent. below that of the solid.

It is not improbable that leather shod wheels may be found to give good results, at least for some types of motor cars, as this substance forms, especially when subjected to powerful compression, a very lasting tyre which has sufficient elasticity to absorb the bulk of the vibration due to the shocks occasioned by passing over obstructions and uneven surfaces.

Segmental blocks of wood have been likewise employed, and are said to form both a durable and efficient tread.

CHAPTER II.

EARLY EXAMPLES OF STEAM ROAD CARRIAGES.

THE three principal sources of energy at present in use for the propulsion of vehicles upon common roads are steam, oil, and electricity, and of these there is no question, at least in the author's mind, as to the superiority of the first for general purposes.

There can indeed be little doubt but that the vast majority of people would prefer a smooth-running reliable steam-engine for use as the propelling medium of a pleasure or light business carriage to the evil-smelling, dangerous, wasteful, and at best uncertain and unreliable oil motors heretofore chiefly employed for that purpose in motor cars of recent construction. Therefore until such time as a completely odourless, (waste) vapourless oil engine has been produced, and until the erratic starting of these motors has been cured, and the necessity for maintaining the said motors constantly running, even whilst the vehicles are stationary, has been eliminated, the oil motor cannot claim to be suitable for the purpose of pleasure and other light vehicles, or for any in crowded thoroughfares.

On the other hand, turning to the true and legitimate field of mechanical locomotion on the public roads, which is obviously that of the conveyance of

comparatively heavy loads of passengers and goods, and probable successful competition with light railways for opening up remote districts, oil motors and electricity are evidently entirely out of the question, and the steam-engine is undoubtedly the only practical source of energy at present available.

It is not proposed in this little work to follow step by step the experiments that have been made in the application of steam power to the propulsion of carriages upon common roads since its first inception over a hundred years ago. The space at disposal is, as has been already mentioned, extremely limited, and consequently any lengthy descriptions of the principal of these earlier attempts, or indeed any mention at all of many of them, would only result in the crowding out of far more interesting matter of more recent date. This portion of the description will therefore have to be confined to a very brief sketch of the more important early types of steam motor carriages adapted for use on common roads.

The first power used for propelling carriages was naturally the steam-engine, and although oil engines have seemingly produced more satisfactory results as the motive power on light carriages of recent construction, there can be but little doubt in the mind of any thinking engineer that the first named will yet prove itself to be equal if not superior to any other form for all classes of power-propelled vehicles.

Authorities differ as to whom the honour is due of having first suggested the use of a steam-engine for the purpose of propelling carriages on common roads. Savery is said to have sufficiently indicated that he considered such a use possible; but, however

that may be, in a patent taken out by Watt in 1784, a description of the application of a steam-engine to the propulsion of road carriages is to be found, an idea which was doubtless the outcome of a suggestion made to him by Dr Robinson, who likewise first directed his attention to the steam-engine. This is probably the first authentic record—at least in this country—of a power-propelled road carriage, and it was speedily followed by the construction in 1786 by Murdoch, Watt's assistant, of a steam-carriage which was run upon the high-road near Redruth, Cornwall. In this same year also a working model of a steam-carriage was constructed by William Symington, the reputed inventor of the steamboat, to whom the idea most probably first occurred about the same time as to Watt; and Oliver Evans, an American inventor, likewise constructed a working model of such a vehicle about this time. Some years later (1802) further experiments with a steam-carriage were made by Trevethick and Vivian, but the wretched state in which the so-called main roads were then kept in this country, the opposition of the turnpike managers, and most probably still more the attraction of all enterprise and capital to the improvement of railways, the introduction of which had then commenced, seemed to have stopped further attempts in this direction at that period. Trevethick and Vivian's patent, dated in 1802, comprised a high-pressure steam-engine, to be used to propel a carriage or waggon, which engine was of particularly ingenious construction, and although of so early a date possessed details which, somewhat modified, were to be found in high-pressure steam-engines of comparatively recent times.

From this attempt for a period of about thirty years the subject was left in abeyance, no further experiments, or at least none worth recording, having been made, until those of Griffiths, Brunel, Gurney, and Hancock, when steam-carriages constructed by these inventors were run for some time in different parts of England and Scotland with considerable success as far as the mechanism was concerned, but failed to prove profitable as commercial undertakings, chiefly, no doubt, owing to the heavy tolls which were levied upon them, and to the obstructions that were everywhere thrown in their way, their very success as practical mechanical contrivances having raised up a host of enemies against them.

Gurney's Steam Road Carriage.

One of Gurney's engines, which weighed only 2 tons, is said to have drawn with ease a load of 11 tons upon a good hard country road. It had tyres 3½ inches in width on the driving wheels. Gurney in his steam-coaches drove direct on to a cranked axle carrying the driving wheels, which were the rear ones, and he placed his cylinders horizontally.

For raising the requisite supply of steam he employed a generator consisting of two horizontal drums connected by a series of tubes bent into a horse-shoe shape, and so placed that the lower arms formed the fire-bars and supported the fire. A third larger drum, placed vertically above the other two constituted the steam space.

The steering was effected by means of a fifth wheel through which the fore carriage was controlled, this

being a practically similar arrangement to that subsequently used on traction engines.

A fatal defect in Gurney's steam-coach was that the portion forming the coach appears to have been the only part supported upon springs, consequently the machinery would become rapidly shaken to pieces by the jars and vibration occasioned by passing over rough roads or pavement. Gurney's coaches are said, however, to have run for several months on the roads between Gloucester and Cheltenham.

Hancock's Steam Road Carriages.

Following on the experiments of Goldsworth Gurney came those of Walter Hancock, who built a steam-coach to carry sixteen passengers, which plied for hire in 1831. Other steam-carriages constructed by the same inventor, all or most of which were of the double-body coach type, are said to have run for a considerable period between Paddington and the Bank, and likewise to have made frequent trips to Windsor, Brighton, and other places. Internal dissensions and disputes occurring amongst the members of the company that had been formed to work these steam-carriages resulted, however, in the stoppage of the undertaking.

One form of Hancock's steam-carriage weighed, when carrying supplies of water and fuel, but without passengers, 3½ tons. The engine was located at the rear of the carriage, and the two hind wheels were the drivers. A separate crank shaft was employed, and was coupled to the wheel axle by means of a driving chain and suitably grooved and toothed rollers. One

of the driving wheels could, and generally was disconnected from the engine, except when climbing a hill.

A special feature of Hancock's steam-coach was the form of steam generator employed. This boiler consisted of a number of iron chambers or compartments placed side by side, with a small intervening space or clearance between each of them, the said compartments being clamped or fixed in position by bolts passing through connecting tubes placed at the top and bottom of the compartments, and forming steam and water communication between them. These compartments were placed above the fire-box within a fire-clay lined casing, so that the flames from the fire could pass up into the above-mentioned spaces or clearances left between them. The fire was blown up by a rotating fan worked from the engine, no chimney being visible, and the forced draught producing very perfect combustion. To prevent any loss of time owing to the fire-grate becoming choked by clinkers and necessitating clearing, he devised an arrangement of fire-bars with a rack on the under side, so that they could be withdrawn by means of a pinion which could be operated through a suitable handle, whilst at the same time a fresh set was inserted in position. Upon cooling the clinkering of the withdrawn bars could, of course, be easily effected, and they were ready for reinsertion at the proper time.

The entire construction was mounted upon springs, and the steering was effected by means of a fifth wheel and chain gearing, from a large drum to a small one fixed upon the lower end of the steering pillar.

Further information respecting Hancock's inventions and many useful particulars may be obtained,

by those interested, from his work upon the subject, published in 1838, entitled "Narrative of Twelve Years' Experiment of Steam Carriages on Common Roads."

Further Early Types of Steam Road Carriages.

Contemporaneous with the above were Summers & Ogle, Church, Dance, Macerone, James, Hill, and a number of other experimenters in this field, but as they did not succeed in producing anything in advance of those mentioned, their steam-carriages may be passed over without notice. Indeed the success of railways, which about this time had become assured, and the difficulties attending the running of locomotives on ordinary roads, owing both to the almost universal poor condition in which the latter were still kept, and to the venomous opposition with which the steam-carriages were again met on every hand, caused practically a total cessation of the attempts to produce more perfect machines; in fact, so far as road locomotives are concerned, it may be said that little or nothing was done from the date of Hancock and Gurney's steam-coaches until the subject was revived about 1856 with the view of adapting such engines to agricultural purposes. Of these several varieties have been constructed which more or less successfully fulfil the duties for which they are intended, but as they are designed solely for the haulage of comparatively heavy loads at slow speeds, whilst the object of the present book is to treat of motor cars or carriages adapted for the transport of passengers or goods at

comparatively high speeds, it would be idle to here enter into any description of that type of road locomotive now universally known as traction engines.

Steam-carriages of lighter construction for passenger traffic were also built about this time by Garrett, Boulton, Tangye, Ricketts, and others, all of which, however, appeared to have been also unsatisfactory, and apparently inferior to those that had been designed many years before by Hancock and Gurney.

Later and more successful of these early attempts were made by Yarrow & Hilditch, Rhodes, Holt, Knight, Catley & Ayres, Todd, Randolph, Grenville, Mackenzie, Blackburn, and Thompson. The efforts of these inventors may be said to have completed the experimental stage so far as steam-carriages are concerned, and to bring the latter up to the present time.

Yarrow & Hilditch's Steam Road Carriage.

The earliest of these vehicles, or that of Yarrow & Hilditch, was built in 1862.* It was capable of carrying eleven passengers, besides a steersman and stoker. The driving wheels were 3 feet diameter, and outside cranks were used. The cylinders were each 5 inches in diameter by 9 inches stroke, and the necessary steam was supplied by an ordinary vertical tubular boiler having an outer shell of steel. It was 2 feet in diameter by 3 feet 9 inches in height, and had 40 square feet of heating surface, the fire-grate being 21 inches in diameter. To reduce the chance of priming, a perforated steam pipe was fitted round the

* For full description of this steam-carriage, see "Proceedings," Society of Engineers, 1862.

top. The boiler was mounted at the rear of the car, and a suitable tender or platform was secured at the same end for the stoker. When fully loaded the weight of the car was about $2\frac{1}{2}$ tons, about 2 tons of which load was carried upon the rear wheels, and half a ton upon the front ones.

Rhodes' Steam Road Carriage.

Another steam-carriage was also built about a year later than the above (1863) by S. G. Rhodes. In

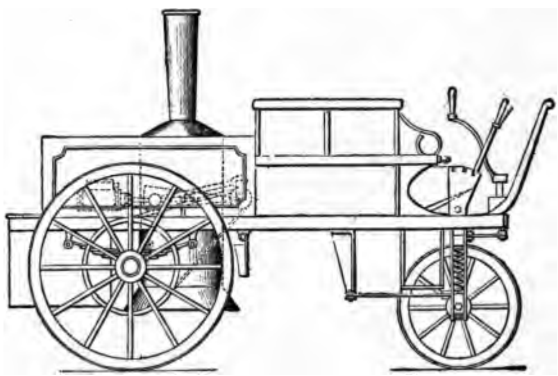

FIG. 1.—Rhodes' Steam Road Carriage (1863).

this arrangement, which is shown in side elevation in Fig. 1, the two cylinders, which were $3\frac{1}{8}$ inches bore by 9 inches stroke, were connected to one crank shaft, the cranks being at right angles, and a chain pinion was provided at each end to drive the road wheels, the gearing being 5 to 1. Primarily both wheels were equally driven, and consequently there was no provision for turning corners or running round curves,

but subsequently the crank shaft was divided, so that each engine ran independently.

Between the axle of the two rear driving wheels and the frame were powerful leaf springs, connected by radius rods to the crank shaft of the engine. A single front steering wheel was used, which was mounted in a fork fitted with sliding bearings resting upon spiral springs, and coupled to the steering handle by means of links.

The boiler for supplying steam to the engines was 2 feet in diameter by 3 feet 6 inches in height. It was fitted with seventeen Field tubes and thirty-six flue tubes into smoke-box, and the working pressure was 150 lbs. per square inch.

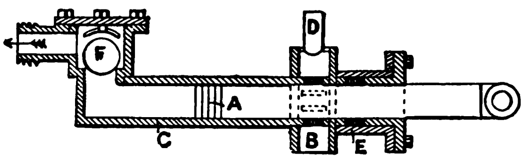

FIG. 2.—Rhodes' Feed Pump.

The feed pump, which was of special construction, is shown in the sectional view (Fig. 2). It is said to have lifted water in a state of ebullition a height of 3 feet, and to have easily forced it into the boiler. Referring to the illustration, A is the plunger, which is fitted with rings on its end; B is an annular casing or cage, situated round the barrel C of the pump, and over the slots therein, and to which cage is connected the water inlet pipe D; E is the plunger stuffing box and gland, upon which, however, no pressure is thrown during work; and F is a ball delivery valve. The ringed plunger A, it will be seen,

would bare the slots in the pump barrel at the termination of each stroke, at which point it would be moving slowly, and coming to a stop. This pump was worked from one of the crossheads of the engine.

A portion of the exhaust steam was passed into the feed-water tank or reservoir, and the remainder discharged into the chimney, a double cone blast nozzle being employed to render it noiseless. The whole of the machinery was completely enclosed by a suitable casing, and this steam-carriage is stated to have been capable of running at a speed of 14 miles an hour on the level with ease, and is also said to have been perfectly successful, and to have remained in use for many years.

Holt's Steam Road Carriage.

A steam-carriage somewhat resembling the above was constructed by H. Percy Holt, A.M.I.C.E., in 1866. In this case, however, a pair of engines, consisting of four cylinders, each 3 inches in diameter by 6 inches stroke, were employed as motive power. The pistons of these engines were connected through suitable connecting rods and link motion with two separate crank shafts, the cylinders being set at an angle, as shown in Fig. 3, which is a diagramatical view, representing the carriage in side elevation. On the outer end of each of the crank shafts was keyed a chain or sprocket wheel, connected by a suitable pitch chain with another chain or sprocket wheel upon the axle of the rear or driving wheels, the relative proportions of the said chain or sprocket wheels being 3 to 1. Two boiler-feed pumps were used, driven

direct off the crossheads, and the whole of the machinery was boxed or cased in.

The exhaust steam was discharged into the chimney, and to prevent any objectionable noise being caused thereby, it was first passed into a silencer, consisting of a cast-iron box, forming a baffle plate at the bottom of the uptake just above the fire, and therein superheated, after which it was discharged in five continuous jets up the chimney. When required, however, a portion of the said exhaust could be utilised for heating the feed-water.

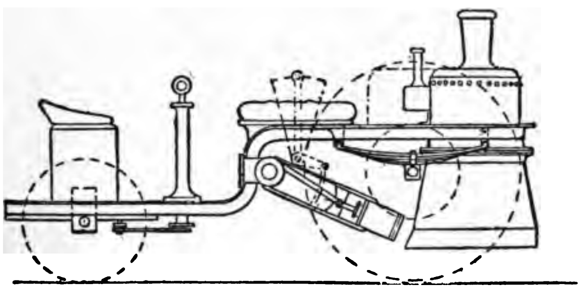

FIG. 3.—Holt's Steam Road Carriage (1866).

The steam for driving the engines was generated in a "Field" boiler, 2 feet in diameter by 4 feet in height, having about 50 feet of heating surface and 3 square feet of grate surface, and working at a pressure of 250 lbs. per square inch. This boiler was hung at the rear of the carriage frame, which latter was formed of light angle-iron 3 inches by 3 inches, and was fitted with a 2-inch safety valve of the Naylor type.

The fore part of the carriage was carried upon a single steering wheel 2 feet 6 inches in diameter, the rear or driving wheels being 4 feet 6 inches in

diameter. A vertical shaft or steering pillar and crossbar was provided for operating the steering, the said steering pillar being connected at its lower extremity to a turntable supporting the steering wheel bearings by a beam and a pair of rods. The rear portion of the carriage was carried upon strong leaf springs.

The levers for reversing the two pairs of engines were so placed that they could be grasped either independently or both at the same time, and the link motions were of the ordinary type, operating valves in a steam chest between the two cylinders. The use of the independent engines admitted of corners or curves being smoothly rounded, and enabled the use of any form of compensating gear to be dispensed with. Either of the said engines could be used with the reversing gear as a brake, and when running upon a good level road one engine only could be used, and the other either entirely cut off, or so linked up that very little steam was used.

This carriage complete, ready for work, weighed about 30 cwts., and it was capable of carrying eight persons, including the steersman and engineman. It is said to have been found capable of ascending gradients of 1 in 14 at a speed of about 7 miles per hour, and to have attained on ordinary roads a speed of from 15 to 20 miles per hour with ease. The consumption of fuel was about 5 lbs. per mile, and the bunkers, which were located on either side of the boiler, were capable of containing a sufficient supply for a 40-mile journey. The water tanks, which were placed on each side of the steering wheel, contained enough feed-water for about a 20-mile run.

Knight's Steam Road Carriage.

Passing on a couple of years, we come to another example of steam-carriages in that built in 1868 by J. H. Knight. As primarily constructed, this carriage had but one steam cylinder, and was fitted with a fly-wheel, the ratio of the gearing being 1 to 6. Owing, however, to very considerable difficulty being experienced in starting when ascending inclines, a second cylinder was subsequently added, and the ratio of the gearing altered to 1 to 4. The frame of the vehicle was composed of two angle irons, and the steam cylinders, which were 5 inches diameter by 7 inches stroke, were located between them, a link motion reversing gear being provided, the reversing quadrant and steam lever of which were upon the steersman's right.

The boiler was of the well-known "Field" type, and had about 26 square feet of heating surface, which boiler was substituted for one of the multi-tubular pattern at first used. A feed pump and a donkey pump were fitted for boiler-feeding purposes. The boiler and engines were located in the rear of the carriage, a platform or footboard being provided for the attendant, and a tank being located beneath the engines of sufficient dimensions to carry 40 gallons of water, which supply would be about enough for a 7 miles run. Storage room for coal for from 14 to 18 miles was also provided.

The rear portion of the carriage was supported upon two 4-feet wheels placed 4 feet 2 inches apart, one of which formed the driving wheel; and the fore carriage was supported through a strong plate or leaf spring

upon two other wheels of 2 feet 8 inches in diameter, and placed only 2 feet apart, which were the steering wheels, and could be operated by a tiller with a cross handle moving through an arc twice the radius of the said wheels, and thus ensuring the requisite power.

The weight of this carriage in running order was about 33 cwts. Three people could be accommodated sitting side by side on the transverse seat, which was situated at the front end of the vehicle.

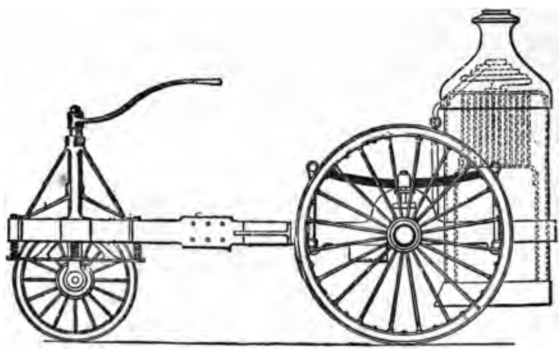

FIG. 4.—Catley & Ayres' Steam Road Carriage (1869).

Catley & Ayres' Steam Road Carriage.

Catley & Ayres' steam-carriage, which is shown in side elevation in Fig. 4, was constructed in 1869. This vehicle, which possesses many points of interest, was exhibited at the Yorkshire Agricultural Society's Meeting in 1871, and a brief description of it will be found in Fletcher's "History and Development of Steam Locomotion on Common Roads."

The propulsion was effected by a double-cylinder horizontal engine, each of the cylinders being $2\frac{5}{8}$ inches

in diameter by 5$\frac{3}{4}$ inches stroke, driving a short crank shaft having a crank at each end placed at right angles to each other. The pistons of the engine were forged with the piston rods, and had grooves cut in them for two steel piston rings each ^{3} inch in width by $\frac{1}{8}$ inch in thickness. The slide bars and crossheads were made of wrought iron for the sake of lightness, and the wearing surfaces case-hardened. The slide valves were operated from eccentrics keyed upon the crank shaft, one on each side of a toothed driving pinion, and suitable bearings between the latter and the cranks were carried upon side plates between which a wrought-iron flange plate was riveted. The above-mentioned toothed pinion geared or meshed with a toothed wheel on the rear or driving axle, the diameter of the latter being three times that of the former. One of the rear wheels only was keyed upon the axle and formed the driving wheel, the other was rotatably mounted thereon, so as to facilitate rounding curves and corners.

The front wheel was supported in a fork, the spindle of which was mounted in a double wrought-iron guide riveted to the fore part of the frame. On each side of the steering fork were four arms secured to a ring or turntable arrangement encircling the wheel, which ring was fitted to turn in four cast-iron guides mounted on spiral springs and held in position by the front end of the frame. The weight of the front part of the vehicle was carried upon these spiral springs, that of the rear portion was carried upon long plate springs connected through sliding axle blocks with the rear axle. The crank shaft and rear or driving axle being in line horizontally, the vertical

movements of the latter were not found to interfere with the working of the toothed wheels to any appreciable extent, so long, however, that is, as the surface of the ground was not too rough, and that the said movements did not in consequence become too violent. The rear or driving wheels were 3 feet 6 inches each in diameter by 2 inches on face, and the front or steering wheel was 2 feet in diameter; the former were fitted with lever hand brakes. The length of the entire carriage was only 8½ feet, and the total weight of the apparatus when the boiler, tanks, and bunkers were fully ready for a journey, was only 19 cwts.

Steam was supplied by means of a boiler of the vertical fire-tube type, built of Lowmoor iron plates. It was 3 feet in height by 17½ inches in diameter, the shell plates being $\frac{5}{16}$ inch, and the tube plates $\frac{7}{16}$ inch thick. In the smoke-box was fitted a spiral tube superheater of 1¼-inch piping, through which the steam passed on its way to the cylinders. A polished copper casing was fitted over the iron smoke-box and chimney, and the boiler was lagged with non-conducting material and a mahogany casing, thereby imparting a handsome and finished appearance to the carriage. It was tested by hydraulic power up to 400 lbs. per square inch, and the working pressure was 150 lbs. per square inch.

It is said to have been found in practice that good coal gave off very little smoke. Coke, however, was of course preferable as fuel. A speed of about 20 miles an hour could be made on a level road; hardly any noise is stated to have been made by the carriage when travelling, and there was practically no vibration.

Todd's Steam Road Carriage.

A three-wheeled steam-carriage constructed two years later still, viz., in 1870, by L. J. Todd, was fitted with an engine having two cylinders placed vertically. They were 2½ inches in diameter by 4 inches stroke, and were each located in a box in front of a coal-bunker on either side, so as to be completely protected. Each of these engines was arranged to drive one of the rear wheels through cones and a gut band or belt; the said rear or driving wheels were 4 feet 6 inches in diameter.

The boiler was 16 inches in diameter by 3 feet 9 inches in height, and was fitted with a considerable number of Field tubes 1 inch in diameter; the heating surface was 16 feet, and the grate surface .75 feet.

The front wheel which formed the steering wheel was 2 feet in diameter, and was controlled by means of a worm upon one end of a horizontal shaft gearing with a toothed quadrant upon the fork carrying the said wheel, the other end of the said shaft having a suitable handle for operating the same.

The carriage was 8 feet 6 inches in length by 4 feet 6 inches in width, and carried two persons. It is stated to have been found to be a practical success.

Randolph's Steam Road Carriage.

A steam coach was built about the year 1872 by Charles Randolph, one of the partners in the celebrated firm of Randolph & Elder, of Glasgow. This vehicle was successfully run during several trips, when its use in the streets was said to have been prohibited, and it was laid up until 1878, at which time it again

appeared before the public at the Paris Exhibition. Subsequently it was presented as a gift to the Patent Commissioners, who did not want it, but kept it under protest, having many times, however, threatened to break it up if not removed by the owner. This year (1896) it took a prominent place as an object of interest amongst the exhibits at the Crystal Palace.

It is a most ingenious vehicle, and contains much that might be imitated with advantage. The mechanism and other parts are very well made, but owing to the manner in which it has been stored and treated by the Patent authorities, the whole is most unfortunately in a deplorable state of dilapidation. A fair description of this steam-coach appeared in the *Glasgow Herald* of 13th November 1872, which was reproduced *in extenso* in the *Engineer* of 6th May 1896. The following are, however, the most essential features of its construction, as abridged from the above:—

The carriage is 15 feet in length, and comprises three compartments, that for the passengers being situated centrally, that containing the boiler and engine at the rear, and that for the steersman, which is set on a higher level, in front, and which latter compartment is also arranged for the accommodation of two passengers. The engines are vertical, two pairs being provided, one on each side of the carriage, the cylinders being 3 inches in diameter. They are quite apart from each other, so that when a curve is being passed round the engine and wheels on one side of the carriage can accommodate themselves to the situation by acquiring increased velocity in proportion to the extent of the curve which is being described.

The boiler is of the vertical type, and is fitted with Field's patent tubes. It was tested at the time of construction to 250 lbs. per square inch by hydraulic pressure, and the working pressure was fixed at 120 lbs. per square inch. The feed-water for the boiler is carried in a reservoir capable of containing an eight hours' supply, which reservoir being interposed between the boiler and the central compartment, also serves to keep the latter cool. The boiler is fed by two of Freidman's patent injectors. The waste steam from the safety-valves, as also the eduction from the engines, passes into a single pipe, by which it is conveyed into a chamber which surrounds the funnel on the top of the boiler. This chamber is so large in proportion to the amount of escaping steam that pulsation is entirely avoided, and the pressure is reduced to equability. The steam is discharged from the chamber into the funnel in a thin annular stream, which surrounds the effluent gases rising from the fire beneath, thus acting as a blast, and obviating the sudden screech and snort that would be otherwise produced. No steam is permitted to escape into the boiler and engine compartment, and the emissions from the funnel when working are said to have been almost nil.

The body of the carriage is mounted upon springs of special construction, by which all jolting was said to have been proved on trial to have been eliminated. The front wheels, which are 3 feet 4 inches in diameter and 2½ inches in breadth, are placed only 2 feet apart, and completely below the fore part of the body, for convenience of steering; the rear wheels are 4 feet 6 inches in diameter by 4 inches in breadth, and are placed 5 feet 4 inches apart, which is the gauge of an

ordinary omnibus. The latter, which are also the driving wheels, are each provided with a spur wheel bolted on the side next the carriage, and are driven by a pinion upon the crank shaft of each pair of engines.

In the front compartment a suitable seat is provided for the steersman, who also acts as engine-driver, a lever depending from the roof at each side of him enabling him to control both the brake power to both the sets of engines driving the hind wheels, by operating that on the right, or to reverse the direction of motion by operating that on the left, and so acting upon the ordinary link motions. The steering pillar rises through the centre of the compartment, and is surmounted by a horizontal steering wheel. This steering apparatus is directly connected with the wheels, an ingenious piece of mechanism preventing its being affected by the jolting of the latter. A pointer indicates at all times the position of the steering wheels to the steersman. In the front compartment are also located a steam gauge, so that the steersman may at any moment ascertain the exact pressure in the boiler; a mercury gauge, exhibiting the precise acclivity or declivity of the ground that is being passed over; and a mirror in front, showing the condition of the road, or the traffic that may be coming on behind. Both the steersman and stoker or fireman can communicate with each other by means of bells, and the latter assistant is provided with a seat in the rear compartment or engine-room, and takes the requisite fuel from a bunk close at hand.

The central compartment is sufficiently high to admit of an average man standing therein with his

hat on. Beneath the fore compartment is a boot, either for luggage or for a further store of fuel for long journeys.

This steam-coach is, notwithstanding its large dimensions, very light, only weighing 2½ tons when empty. When, however, supplied with fuel, water, &c., for a long journey, and filled with passengers, its total weight would be about 4½ tons.

Grenville's Steam Road Carriage.

Another steam-carriage, which is yet in existence, was designed by and constructed for R. Neville Grenville in 1875. As in the case of Knight's steam-carriage, a single cylinder was first employed, but this arrangement being found unsatisfactory, two were afterwards substituted, and placed horizontally instead of vertically, as was the case with the single cylinder. The two cylinders are each 5 inches diameter by 6 inches stroke, and the ratio of the crank shaft to the driving wheels is 4 to 1.

The boiler is of the cross-tube steam fire-engine type, by Shand & Mason, and has a fire-box heating surface of 13 feet and tubes of 16 feet, or 29 square feet altogether. The fire-grate area is 2½ square feet.

The second motion shaft is connected to the driving axle at the right-hand end, and springs are provided so as to cause it to rise and fall with it. At the other or left-hand end is a ball and socket bearing, the gear teeth being thus thrown slightly across each other, but in the same plane, thereby preventing any injury or unevenness of wear resulting therefrom. In the latest arrangement of the mechanism an exhaust tank and

feed heater is provided, but formerly the exhaust was turned into the feed-water tank when required; the water from the condensed steam is run back into the feed-water tank, which latter is capable of holding 55 gallons. An injector and a pump are provided for feeding the boiler.

The wheels are of the disc pattern, and of teak with iron rims, the rear or driving wheels being 4 feet in diameter by 3 inches in width; the single steering wheel is 2 feet 6 inches in diameter and the same width.

The weight of this steam-carriage, with supplies of coal and water for a run, is 45 cwt. There are two seats in front, placed crossways and one behind the other, and suitable accommodation for the engine and boiler attendant is provided at the rear.

Although of only three years more recent date than that just described, owing to its having been treated with reasonable care, this carriage is still in perfect working order, and has just lately made several successful runs.

Mackenzie's Steam Road Carriage.

A close steam-carriage built in the same year as the above, by H. A. O. Mackenzie, was mounted upon three wheels, and had an engine with two cylinders of the vertical type, the diameters of which were $3\frac{3}{4}$ inches, and which had $4\frac{1}{2}$ inches stroke, an ordinary link reversing gear being provided. Two toothed wheels of different diameters were so arranged that either of them could be caused to engage or mesh with one or other of two spur or toothed wheels upon a second motion shaft

having at its centre a compensating gear, and at each end suitable chain or sprocket wheels, whereon, and upon toothed rings upon the road wheels, ran two pitch or driving chains, the speed of the engine as compared with that of the road wheels being either as 6 to 1 or as 13 to 1, in accordance with the wheels in gear at the time. The higher degree of speed enabled the carriage to travel at the rate of from 10 to 12 miles an hour. Intermediate speeds were obtained by the regulation of the engine, and steam was provided for working the latter from a boiler of the Field type, 4 feet high by 2 feet in diameter, and having about 34 square feet of heating surface and 1.76 feet of grate surface, working at a pressure of 135 lbs. per square inch, and which boiler was fed by an injector from a water-tank fitted with a suitable strainer. A cast-iron receptacle was provided at the bottom of the chimney into which the exhaust steam was delivered, and from the centre of which it issued up the said chimney, and a blast valve was also used, and was, when the road surface was such as not to require a powerful blast, kept only slightly open. This valve acted as a variable blast, admitting of the back pressure in the cylinders being reduced when required.

The chain wheels were fitted with teeth which admitted of adjustments being made for wear, and radius rods connected to the chain pinion bearings and to the axle were provided for maintaining the proper distance between the said chain wheels.

One of the axles, viz., that carrying the two wheels, was bent to take in the boiler. The wheels were the ordinary type of wooden carriage wheels with the usual iron tyres, the drivers being 4 feet in diameter

and fitted with lever brakes, and the single steering wheel 2 feet 6 inches, and connected by means of suitable rods with a steering pillar surmounted by a hand wheel.

Blackburn's Steam Road Carriage.

Blackburn's steam dog-cart, for which a patent was granted in 1877, was fitted with a torpedo engine.

Steam was supplied by a boiler composed of coils of tubes, petroleum fuel being employed, and the fire blown up by a blast from a fan or blower worked by the engine. The exhaust steam was condensed in an air condenser, wherein it was delivered into a large number of tubes located round the circumference of a fan or blower in such a manner as to be constantly subjected to the cooling action of a powerful current of air.

Thompson's Road Steamer.

Thompson, of Aberdeen, designed a type of traction engine known as a road steamer, several of which were run for many years on a number of the trunk roads of Northern India, working regular services of trains for both goods and passengers.

The provision of narrow gauge railways, however, rendered this method of transporting goods and passengers unnecessary, and their use was consequently discontinued.

Thompson was the first to apply indiarubber tyres to the wheels of road locomotives.

CHAPTER III.

Recent Examples of Steam Road Carriages.

Coming now to steam-carriages of more recent date, we may take as fair examples of what has been done in this direction, those of Serpollet, Le Blant, De Dion & Bouton, Hartley, Thornycroft, Simonds, and Sautenard, the two latter of which are of the steam velocipede class.

The advantages of the steam-engine have been already alluded to, and will be easily understood when it is remembered that it affords a very large capacity of regulation of power, is capable of being readily fitted with reversing gear, is easily managed, and can be stopped or started on the instant, and without the slightest difficulty; and as water and fuel are practically everywhere obtainable, is therefore adapted for universal use. As against these obvious advantages must be placed the objection that the working medium, *i.e.*, steam, has to be produced on the road, thereby necessitating the use of a heavy, cumbrous, and more or less bulky boiler or generator. It is in this generator indeed that the great obstacle to the satisfactory use of steam lies. The steam-engine itself can be readily made extremely light, and

yet be thoroughly efficient, but the construction of a boiler or steam generator of the requisite power and of sufficient lightness is a problem the solution of which is beset with much difficulty. The flashing boiler, with its instantaneous generation, ceases to make steam on the stoppage of the engine and feed pump, is very safe, and possesses many other advantages for the purpose in question; but on the other hand, the reserve of thermal energy is very small, and is soon exhausted when drawn upon, thus making but little provision for emergencies. The tubes and their casing also are very heavy, and the said tubes, moreover, are rapidly destroyed by the great heat to which they are naturally exposed. On the other hand, again, the high pressure boiler, whether of the water-tube or other type, whilst affording great power, continues to make steam during a temporary stoppage, and consequently gives rise to blowing off and waste, a defect which, however, could be considerably modified by the provision of some arrangement for arresting the combustion or radiant heat upon the stoppage of the carriage.

Serpollet's Steam Road Carriage.

The first of the more recent types of steam road carriages, to be noticed in point of efficiency, is that fitted with the Serpollet generator and motor, the former of which has proved itself fairly adapted for the purpose in question, enabling as it does a pressure of from 15 to 20 atmospheres to be easily maintained by the simple injection into the series of tubes of which it is composed of a continuous stream of water,

the said pressure being capable of being temporarily raised still higher, upon any emergency arising, by simply increasing the amount of the said feed.

Messrs Serpollet have been for a considerable time past experimenting in steam-carriages, and have produced some very efficient machines, one of their latest types being illustrated in the longitudinal sectional diagramatical view (Fig. 5). In this view, M indicates the motor, which is located forward beneath

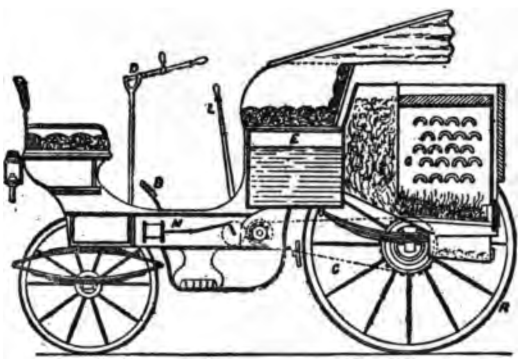

FIG. 5.—Serpollet's Steam Road Carriage.

the floor of the carriage, where it is enclosed so as to completely protect it from dirt and injury; G is the boiler or generator, which is situated at the rear, and is supplied with feed-water from the feed-water tank E, placed, as shown in the illustration, beneath the main seat of the carriage; R is one of the rear or driving wheels, which is connected to the motor shaft through chain or sprocket wheels and pitch chain C, and toothed gearing, as described later; B is the foot lever for operating the brake mechanism; L is the

starting and stopping lever; and D is the steering gear.

The motor M has two cylinders, and a Stevenson link reversing gear is provided. The steam is admitted during 70 per cent. of the stroke. The connecting rods are coupled to a cranked shaft carrying a pinion, which latter gears or meshes with a second toothed wheel or pinion mounted upon another shaft, at the ends of which are fixed the chain or sprocket wheels, which communicate motion to the driving wheels through the pitch chains C, and other chain or sprocket wheels of larger diameters formed on the wheel hubs.

The motor also drives the feed pump, which has a cylinder .98 inch in diameter and .79 inch stroke. The lubrication of the engine is provided for by a very efficient automatic arrangement, which renders the necessity for any frequent examination and lubrication of the working parts thereof when travelling unnecessary.

The generator, which is placed at the rear, and enclosed in a suitable casing, as shown in Fig. 5, is, however, the most important part of the machinery, and it is by the particular form and disposition of tubes used in this generator that the Serpollet carriage has succeeded in producing such favourable results. The principle upon which it operates, which is that of flashing the feed-water into steam, is not new, and is identical with that of boilers designed by Payne (Brit. Pat. No. 555, of 1736), Howard, Parks, and others many years ago, and with that of the well-known little engine and generator, known as the Tyson Vase engine, which has been in use for many years in the United States and elsewhere by dentists and others requiring small power.

The main novel feature of the Serpollet generator is the peculiar form of the tubes in transverse section, which, as also their arrangement in the boiler, will be apparent from the transverse and longitudinal sections (Figs. 6 and 7), which represent a generator of the latest type. The tubes, it will be seen, are not circu-

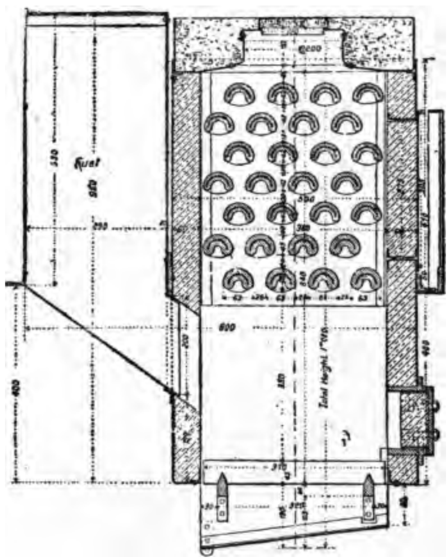

FIG. 6.—Serpollet Steam Generator (Transverse Section).

lar, but are so formed as to have one concave side, which, however, does not extend quite to their ends, these latter being left circular for convenience of attachment thereto of the return bends or heads. The tubes are of thick steel, solid drawn and weldless, and are stamped after drawing, so as to produce the desired concavity. In the boiler illustrated the tubes are of

the smallest section made, viz., 2.48 inches, and the second row from the bottom one is placed at a distance therefrom of .98 inch, this clearance being gradually reduced until that between the last but one from the top tube and the latter is only .71 inch. The set of tubes weighs about 3¼ cwts. The

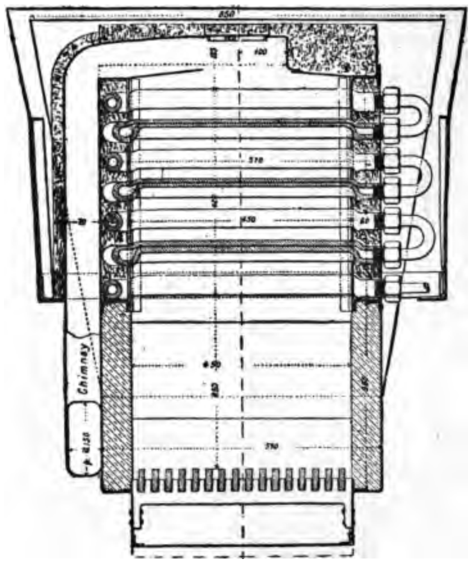

FIG. 7.—Serpollet Steam Generator (Longitudinal Section).

height of the boiler is 37.40 inches, and its largest diameter is 31.50 inches. The grate-bars are 14.57 inches in diameter, and the total heating surface is 26.9 square feet. The fuel reservoir or bunker is located in front of the generator, and the fuel is fed therefrom to the grate automatically.

Inside the boiler casing is placed a lining of fire-

bricks or other refractory material, and to still further prevent the radiation, and the loss of heat resultant therefrom, there is also a layer of silicate cotton or slag wool. This latter material is also employed to jacket the chimney for a certain portion of its length. A fire-door is provided, as also another door or manhole, through which the outside of the tubes can be cleaned.

Water is injected into the boiler at the base near the fire-grate, where it is practically instantly converted or flashed into steam, the latter becoming superheated as it passes through the upper rows of tubes, and being finally removed by the steam pipe leading to the motor.

The boiler shown in the illustrations is, as already mentioned, fitted with the smallest sizes of these tubes made, which are 2.48 inches external diameter and .39 inch in thickness, weighing 8.9 lbs., and containing 1.3 oz. of water per foot run. This great disparity between the weight of the tubes and the water they contain admits of sufficient heat becoming accumulated in the metal to allow for certain temporary variations taking place in the temperature of the fire, without any marked falling off of efficiency in action, a most valuable property for the duty in question.

The gases generated by combustion are very fully utilised, and the boiler is tolerably economical in fuel consumption. It has been found by repeated experiment that any traces of incrustation that may become deposited in the tubes can be easily got rid of by blowing the boiler off suddenly when under full steam.

These steel tubes, which really form the generator, are tested to 200 atmospheres, and the working pres-

sure is 350 lbs. It will be seen, therefore, that the boiler is practically inexplosive.

In the most recent arrangements petroleum is employed as fuel instead of coke. The ordinary lamp petroleum is used, and the burner is of the Longuemarre type, a brief description and an illustration of one form of which will be found on page 88. The petroleum is admitted at the bottom of the burner, from whence it is forced up through a spiral tube, wherein it becomes volatilised under the action of the heat of the flames, and passing down to the bottom of the burner is cleared of any impurities by a metallic filter. The vapour next passes into a chamber, from which it is transferred through small apertures into a second chamber, wherein are located eight jets, from which the said vapour issues and burns with an intense flame, which spreads out so as to cover the entire area of the funnel constituted by the spiral tubes and the space above it, in which is the generator. The burner is started in the usual manner with a little methylated spirit.

The machinery can be started in from eight to twelve minutes from the time of lighting the burner.

The method of steering used in the Serpollet carriage is that which has been lately devised by M. Jeantaud, and which consists essentially in the employment of a fixed fore axle placed parallel to the rear or driving axle, and terminating at each end in a fork. In each of these forks is placed a T-piece constructed with bearings, and having an extension or journal to carry the wheel, as shown in Figs. 8 and 9. Consequently this arrangement admits of the wheels moving freely in a horizontal direction. The long

arm of each of these T-pieces forms a lever, and a connecting rod maintains these levers constantly at a fixed distance apart, and therefore the wheels parallel to one another. Any movements transmitted to this connecting rod will be transferred to the wheels through the levers, which latter will, however, pass through different angles when shifted. This steering gear enables the carriage to be turned very easily, and with a short radius. On the other hand, however, it is open to the objection that the steersman would apparently be liable to sustain violent shocks when passing over rough or uneven surfaces.

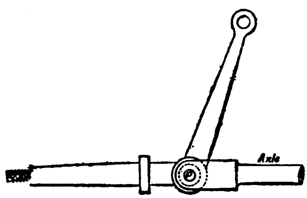

FIG. 8.—Jeantaud Steering Gear (Plan).

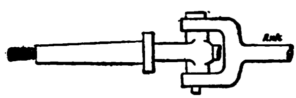

FIG. 9.—Jeantaud Steering Gear (Side View).

The carriage illustrated in Fig. 7 weighs about 13 cwt. 3 qrs. when empty, and about 17 cwt. 3 qrs. when loaded. The speed attainable with four passengers is from 9 to 15 miles or even 22 miles per hour on a moderate grade. The consumption of coke is about 3.5 lbs. per mile, and the cost of lubricating oil from ½ to 1 centime, the above figures being deduced from observations made on trial runs of about 200 miles.

Le Blant's Steam Road Carriage.

Figs. 10 and 11 are diagrams representing respectively in plan and side elevation a Le Blant steam-

carriage, suitable for the delivery of goods from extensive establishments, and adapted to meet the requirements of French customers, who demand a strong and

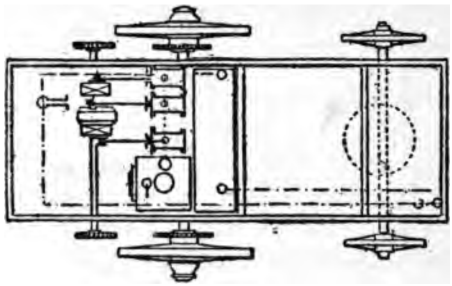

FIG. 10.—Le Blant's Steam Road Carriage (Plan).

easily managed vehicle, capable of passing through the narrowest streets and up the steepest inclines to be met with, having a closed compartment of, at the

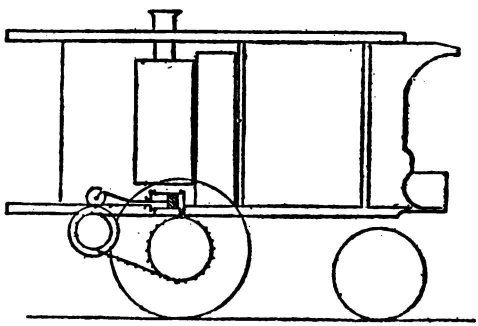

FIG. 11.—Le Blant's Steam Road Carriage (Side Elevation).

very least, 65 cubic feet capacity, and able to carry a minimum load of 1½ ton.

Mr Le Blant is one of those who has taken what is in all probability the right view of the value of motor

cars, viz., that their chief mission will be found to be for comparatively heavy work such as omnibuses, and diligences for passengers, and goods waggons for use in town and country. Therefore whilst having devoted some attention to the construction of brakes and other pleasure carriages, his main object has been to produce an efficient vehicle of the type shown in the illustrations, and also of large motor cars capable of drawing heavy trailing cars.

The vehicle shown in the sketches is built of iron, except the wheels, which are of wood. The frame is of channel irons stiffened with cross-bracings, the latter also of channel sections and 4 inches deep, with a flange 2 inches in width.

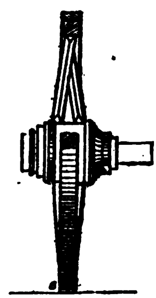

FIG. 12.—Le Blant Wheel.

The wheels, which are as above mentioned of wood, have crossed spokes, as shown in Fig. 12, and are mounted to revolve upon the bearings of a fixed axle. In some later built carriages, however, owing to the trouble experienced with wheels constructed of wood, the inventor has substituted ones made of iron and steel.

The engine, which has three cylinders, each 3.94 inches in diameter, is secured to a frame of channel and angle irons, the crosshead guides being made of a special quality of cast-iron having a considerable degree of elasticity. Steam is admitted during four-fifths of the stroke, which latter is of 4.32 inches in length, and the engine can be run at any speed up to one of 700 revolutions per minute, one of 250 revolutions corresponding to a rate of 11 miles an hour.

The cranks are placed at an angle of 120 degrees, and a pinion on the crank shaft gears with the crown wheel of a differential motion fitted on an intermediate shaft. Power is transmitted to the driving wheels by chain or sprocket wheels and pitch chains.

The steam generator employed is one of the Serpollet type, which has already been described.

The disposition of the mechanism will be apparent from the drawings, wherein it will be seen that in order to ensure as much adhesion as possible, the engine and boiler, as also the fuel and water compartments, are located over the rear or driving axle. The compartment for the goods, which has a capacity of 141 cubic feet, is separated from the boiler by the feed-water reservoir, and any overheating of the said compartment owing to its propinquity to the boiler is thus avoided.

Within easy reach of the conductor or driver, who sits in front, are the injection pump lever, which acts as a speed regulator, the steering wheel, the operating wheel of a screw brake, and two pedals, the one controlling the amount of feed, and the other a strap brake passing round a drum on the axle. A pressure gauge, placed in front enables the said driver to ascertain at a glance the steam pressure available. The stoker or fireman, who is located in the rear, looks after the stoking of the boiler, the variable exhaust, and a hand oil-pump for lubricating the slide valves.

The steering mechanism consists of an ordinary fore carriage, the turning ring of which carries a circular rack with which gears or meshes a pinion upon the lower extremity of the steering wheel spindle or pillar. The teeth of this rack and pinion are of a special form, which has been patented.

De Dion & Bouton's Steam Road Carriage.

The latest type of the De Dion & Bouton motor car is in reality a small road locomotive, which is intended to be coupled to and draw a trailing vehicle, and in fact to take the place of a horse. It is somewhat inaptly styled by the inventors a steam bogie. Owing to the purpose for which it is intended, this motor car, when viewed by itself, gives the impression of being unnecessarily heavy and unwieldy in construction, which, however, is not really the case considering the duty it is required to perform.

A motor of the De Dion & Bouton type performed

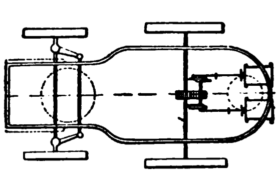

FIG. 13.—De Dion & Bouton Steam Road Car (Plan).

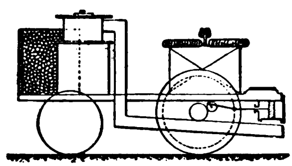

FIG. 14.—De Dion & Bouton Steam Road Car (Side Elevation).

good work coupled to a four-seated victoria, in the *Petit Journal* competition of 1894. This machine has a horizontal frame formed of bars V-shaped in transverse section and 2 inches in depth, which frame is supported on the axles through coach springs, and carries the boiler, feed-water tank, fuel store, and engine.

The disposition of the various parts is shown in the diagrams Figs. 13 and 14, which represent respectively a plan and a side elevation of the vehicle. The fuel store, it will be seen, almost entirely surrounds the boiler, and the chimney dips downwards and is carried

back beneath the car, discharging to the rear, as shown in Fig. 14.

The frame is mounted upon four wheels, the rear pair, which are considerably smaller, being used for steering, and controlled by an arrangement of cranks, on the Jeantaud principle, as shown in Fig. 13.

The engine, which is placed on the carriage below the platform, is of the compound type, the small or high pressure cylinder being 4.72 inches in diameter, and the large or low pressure cylinder 7.08 inches, the stroke of both pistons being 5.11 inches. An

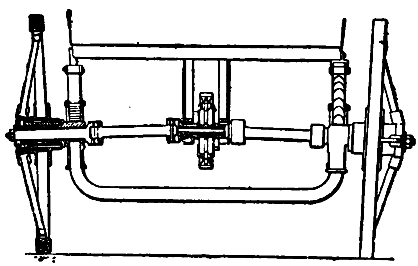

FIG. 15.—De Dion & Bouton Transmission Gear (Sectional Elevation).

intermediate receiver is provided between the two cylinders, and continuous lubrication is ensured by the provision of an automatic oiling device. When desired the full steam pressure can be admitted to both cylinders, and the engine worked as a double cylinder high pressure one. This engine, which is calculated to develop 20 horse-power, is coupled to an intermediate shaft, which shaft carries a pinion gearing or meshing with a toothed wheel on the driving axle or shaft, which latter is connected with the wheels in a special manner, the ratio of gearing

being 2.81, and the running speed, to drive the car at a rate of 12.5 miles an hour, being 300 revolutions per minute.

A special feature in this motor is the manner in which the power is transmitted to the rims of the driving wheels, as shown in Figs. 15, 16, and 17. The object of this arrangement is to avoid the strain that is ordinarily exerted on the spokes, and thereby to prolong their lives. As will be seen from the above-mentioned illustrations, which are drawn to a much larger scale than Figs. 13 and 14, the axle, or what

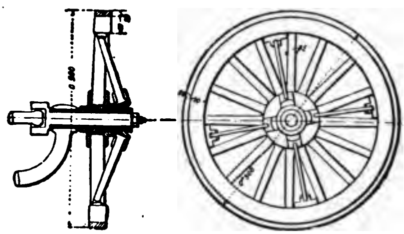

FIG. 17. FIG. 16.

De Dion & Bouton Transmission Gear (Side View and Vertical Section through Wheel).

may rather be more accurately called a supplementary axle, is bent and carries an axle-box at each extremity, on the top of which boxes are placed the springs supporting the frame of the vehicle. Each of these boxes supports one end of a sleeve carrying a wheel on the other end, which sleeve is traversed by a portion of the motion or driving shaft, which is articulated as shown, and which forms the real axle of the wheels. On each end of this articulated shaft, which projects a suitable distance beyond the nave or boss of the wheel, is secured a block or piece having four arms jointed

back beneath the car, discharging to the rear, as shown in Fig. 14.

The frame is mounted upon four wheels, the rear pair, which are considerably smaller, being used for steering, and controlled by an arrangement of cranks, on the Jeantaud principle, as shown in Fig. 13.

The engine, which is placed on the carriage below the platform, is of the compound type, the small or high pressure cylinder being 4.72 inches in diameter, and the large or low pressure cylinder 7.08 inches, the stroke of both pistons being 5.11 inches. An

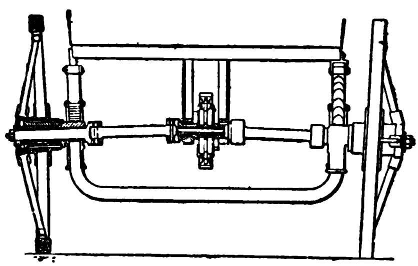

FIG. 15.—De Dion & Bouton Transmission Gear (Sectional Elevation).

intermediate receiver is provided between the two cylinders, and continuous lubrication is ensured by the provision of an automatic oiling device. When desired the full steam pressure can be admitted to both cylinders, and the engine worked as a double cylinder high pressure one. This engine, which is calculated to develop 20 horse-power, is coupled to an intermediate shaft, which shaft carries a pinion gearing or meshing with a toothed wheel on the driving axle or shaft, which latter is connected with the wheels in a special manner, the ratio of gearing

of the internal ring, and a circular diaphragm or baffle being used to prevent any water passing over with it. The upper and lower ends of the two concentric rings are closed by means of circular plates held firmly together by bolts passing through the steam and water spaces; these plates can be thus easily removed, and access had to the said interior spaces for cleansing purposes. The grate is, it will be seen, situated at about a level with the bottom of the outermost concentric tube or annular casing, with the ash-pit below it. A light casing surrounds the portion of the inner ring projecting above the outer one, from the top of which casing the chimney is taken and dips downward as shown, a soot door being provided for cleaning purposes. The fuel is introduced at the middle of the central ring or annular casing, the aperture being normally closed by a sheet-iron cover.

It will be seen that the hot gases from the furnace play upon the surfaces of the concentric rings or annular casings and round the inclined radiating tubes, which afford a very large heating surface, finally passing away through the chimney, which, as shown in Fig. 14, is so bent as to discharge beneath and at the rear of the vehicle. A re-heater is provided at the side of the fire-box, consisting of a flattened and bent steel tube, protected from direct contact with the flames by a cast-iron shield.

The boiler shown in Fig. 18 has a fire-grate 13.4 inches in diameter, and the diameter of the inner ring is only 6 inches; the tubes are copper, .39 inch internal diameter, .12 inch in thickness, and 4.40 inches in length; the heating surface of the boiler is 24 square feet, the grate surface 2 square feet, and the

total weight 530 lbs. The ordinary working pressure is one of 9 atmospheres.

Boilers of this type are guaranteed by the inventor to evaporate from 4.5 to 6 lbs. of dry steam per square foot of heating surface, and from 7 to 8 lbs. per pound of coal, with natural draught.

Trials recently conducted by a French firm of high repute (Sautter, Harlé, et Cie.) with a De Dion boiler having a heating surface of 64.5 square feet, a grate surface of under 3 square feet, and weighing 1,430 lbs. when empty, gave a production of 550 lbs. of steam for a consumption of 88 lbs. of coal per hour.

Although undoubtedly a very efficient steam generator, the De Dion boiler is open to some objection, by reason of its great delicacy of construction. To ensure safety it would require careful handling by a skilled attendant, and most decidedly is not a boiler to be entrusted to the charge of an inexperienced person.

The weight of the De Dion & Bouton road locomotive, shown in Figs. 13 and 14, in working order is 2 tons, and it is stated to be capable of drawing a load of 2½ tons at a rate of 20 miles an hour on a level surface. It carries a supply of coke sufficient for a run of 60 miles, and water for 25 miles, the storage tanks for the latter being located beneath the seat.

Hartley's Steam Road Carriage.

The Hartley steam-carriage is fitted with a two-cylinder rotary steam-engine, the engine valve gear being operated by an eccentric. The steam is generated in a boiler 16 inches in diameter by 20 inches in

height, mounted on the fore part of the carriage. The carriage is mounted upon 36-inch front and 44-inch rear wheels fitted with pneumatic tyres, and running on ball bearings.

The weight of this carriage complete, with engine, boiler, and machinery, is about 6¾ cwt.

Thornycroft's Steam Road Carriage or Van.

The Thornycroft steam-carriage, which is shown in Fig. 19, is of the four-wheeled van type adapted for the transportation of goods, having an available floor space for the latter of about 25 square feet, and capable of carrying a load of 1 ton. The vehicle measures 11 feet over all, and of this 4 feet 6 inches are devoted to the boiler and machinery, and when in full working order, including fuel, and sufficient water for a 20-mile run, as also the driver, weighs 1 ton 15 cwt. Unladen, its weight is about 1 ton 10 cwt., of which about 1 ton 2 cwt. is supported on the driving wheels.

Motive power is supplied by a double compound condensing engine, the cylinders being 2 inches and 4 inches diameter respectively, by 3 inches stroke for both, and they are so arranged that live steam can also be admitted to the low pressure cylinder for hill climbing. The engine is geared through chain or sprocket wheels and pitch chains in the ratio of 9 to 1 to the road driving wheels, which in this case are the front pair. A large sized skew-toothed pinion meshes with the corresponding teeth of the rim of a wheel carrying the compensating gear, which wheel is carried by the two inner ends of the second motion shafts, which carry at their outer ends the chain wheels com-

municating motion to the driving wheels. The chain or sprocket wheels are fixed as shown to the backs of the naves of the driving or road wheels. The bearings carrying the intermediate shaft are connected by radius bars to the main axle, so as to maintain the proper distance between the two sets of chain wheels, and at the same time allow free play of the springs by which the van is carried.

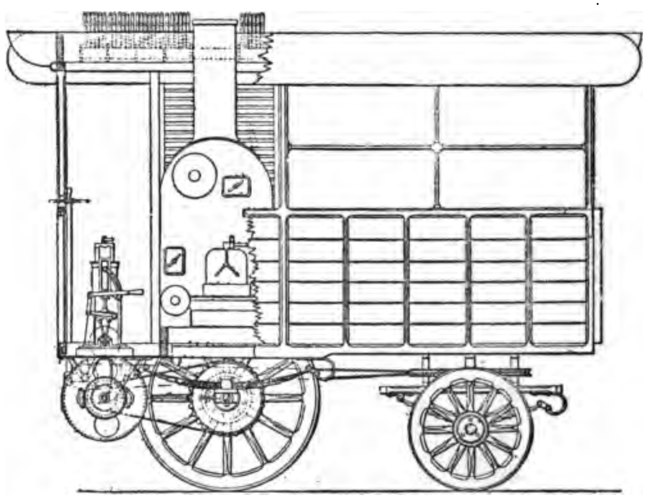

FIG. 19.—Thornycroft's Steam Van.

The rear pair of wheels are of smaller diameter and form the steering wheels, their manipulation being effected by a hand wheel on a vertical spindle, carrying at its lower end a worm gearing with a wheel 8 inches in diameter to which is connected a chain wheel. A horizontal turning wheel on the locking shaft steering wheels is connected by an ordinary link

chain to the chain wheel upon the lower end of the steering pillar.

The boiler used for the generation of steam is one of the well-known Thornycroft water-tube launch type, having 50 square feet of heating surface, and $2\frac{1}{2}$ square feet of grate, and hollow fire-bars through which a circulation of water is maintained, and in which steam can be raised in about fifteen minutes, coke being used as fuel.

The condenser is located as shown in the roof of the van, and has a surface of about 130 feet, the tubes being of thin copper and of a diameter of half an inch, and connected in groups to short lengths of $1\frac{3}{4}$-inch tubes secured together by long bolts. This condenser affords a cooling capacity sufficient for the condensation of all the steam that would be used by the engine at ordinary rates of working.

When fully loaded this steam van is said to be capable of ascending a gradient of 1 in 10. The ordinary rate of speed is intended to be from 6 to 7 miles an hour, but the vehicle can easily be caused, if desired, to travel at 9 miles an hour on level roads.

This steam-carriage is said to have given very favourable results during a recent series of very severe trials. On a late occasion the van, with a load of over 10 cwt., was run from Chiswick to Windsor Castle, a distance of 20 miles, and back again, no stoppage either way being found necessary for adjustment or other purpose, and the castle hill being surmounted with ease. The time occupied in the single journey one way was $2\frac{3}{4}$ hours, and 90 lbs. of coal and coke mixed in equal bulk was consumed in making the run.

Simonds' Steam-Carriage.

The steam-carriage designed and built a couple of years ago by C. L. Simonds is of the velocipede or cycle type, being a quadricycle or tetracycle with bicycle wheels and light body or frame.

The engine employed to propel it has two cylinders, the driving cranks being set at 90°, and the rear axle driven by a sprocket wheel and chain.

Steam for the engine is supplied by a porcupine boiler having 28 square feet of heating surface, and adapted to work at a pressure of 100 lbs. per square inch. Naphtha is used as fuel, provision being made for carrying a sufficient supply for a run of 100 miles. Five burners are provided beneath the boiler, one or more of which can be used as may be desired, and an air pump driven by the engine blows a blast of air through the naphtha. The exhaust steam is first passed through a feed-water heater, and is subsequently delivered to the naphtha flame, where it acts to deaden the noise of the latter. A boiler feed-pump is also worked by the engine.

The total weight of the machine is about 4 cwt., and it is adapted to carry two passengers, with which complement it is said to be able to surmount reasonably steep ascending gradients with ease, and to be capable of sustaining a speed of 10 miles an hour on the level.

Sautenard's Steam Road Carriage.

The Sautenard steam road carriage is likewise a vehicle of the cycle or velocipede type, and is a still lighter machine than the steam tricycle just described.

It is driven by a small tandem engine, so arranged that steam can be admitted to either one or both cylinders according to the state of the road surface being passed over, gradient to be surmounted, &c. The driving wheels are driven by chain gearing, and three different speeds are provided.

The boiler for raising steam, which is located at the front part of the machine, is of a tubular type, which, it is claimed by the makers, is practically inexplosible. It has a heating surface of about 10¾ square feet, and is fired by two petroleum blasts. Sufficient storage capacity is provided to enable a supply of oil or petroleum essence for a journey of a duration of four hours, and of feed-water for covering a distance of about 22 miles, to be carried.

The vehicle is fitted with a steam brake, and the wheels have pneumatic tyres. The carriage and machinery weighs when in working trim considerably under 3 cwt., and is capable of carrying two passengers. The speed attainable varies from 5 to 12 miles per hour, according to the state of the road surface, gradient, &c.

CHAPTER IV.

INTERNAL COMBUSTION OR EXPLOSIVE ENGINE CARRIAGES.

ALTHOUGH it cannot be denied that at certain recent trials, motor carriages, fitted with oil engines as motive power, attained the best results, it must not therefore be supposed that finality has been approached, much less reached, or that the present horseless carriages any more represent those of the future than the "Rocket" of 1829 did one of the express locomotives of the present day.

It is quite true, of course, that the road locomotive is not a thing of yesterday, but one now venerable by its antiquity, and older than the railway locomotive, but various combinations of circumstances have hitherto prevented the development and perfection of those types suitable for effecting a comparatively rapid transit of goods and passengers.

To return to the subject of oil motors, the author, from a careful investigation, and after considering the matter from every point of view, cannot but think that those who look upon them as the ideal source of energy for motor carriages will find themselves greatly mistaken. The objections to the use of motors of this type have been already lightly touched upon. Any engineer

who has ever had anything to do with internal combustion or explosive engines knows what uncertain machines they are to deal with, and how, even when in the hands of skilful men thoroughly accustomed to all their peculiarities, they will occasionally refuse to start, and that for no detectable or even assignable reason. Half an hour, or perhaps more, now and then spent in the not interesting or profitable occupation of turning the fly-wheel of such an engine when used for stationary driving purposes creates undoubtedly much annoyance, and also occasions, if often repeated, a considerable loss; but it has come to be looked upon as one of the inseparable inconveniences and drawbacks of this and of all other types of gas motors or explosive engines, and to be accordingly duly taken into account when making an estimate of their value. In the case of a road vehicle, however, this uncertainty of starting, even in the hands of the most skilful, assumes much more grave importance, for what is here wanted is obviously an engine that can, when once ready, be practically instantly, and whenever desired, stopped or started, or reversed. Another most objectionable feature in oil or other explosive engines is the liability of the various passages to become choked up with deposit to the extent of causing frequent failure in action, and giving rise to much inconvenience. For this reason, all pipes, passages, or ways should be made of ample area.

Explosive engines, moreover, are subject to the well-known conditions that the speed must be nearly constant, whilst a motor for vehicular propulsion should be capable of fine graduations of speed from practically nothing up to its full rate of travel, and

not be entirely, or almost entirely, dependent upon a set of more or less complicated change wheels and gear for effecting one or two alterations of speed.

Moreover, lastly, but not by any means least, the waste products of internal combustion or explosive engines are more offensive than those emanating from a steam generator wherein proper arrangements are made for combustion, and where no escape of steam from engine or boiler need be allowed into the atmosphere. All the present combustion or explosive engines that have been seen by the writer throw off a foul, evil-smelling, and poisonous, smoky vapour (carbonic oxide), which would render their presence in any considerable numbers in the streets of a town an intolerable nuisance, and one too in every case constant, for the oil motor must be kept running in the streets, no matter whether the vehicle to which it is applied be moving or stationary. The spirit engines using light oils, petroleum spirit, benzol, &c., are, of course, far less offensive in this respect than the motors employing the heavy oils, but are still a very long way from being immaculate, and, moreover, the present state of the law in this country precludes the use of the former.

In support of the above statement, attention may here be especially drawn to that part of the report of the engineers in charge of the tests carried out in connection with the Chicago trials of motor cars, in which they say: "Nearly all the single cycle motors burn a great deal of fuel, caused generally by the improper combustion of the gases. This is the case with the Lewis and the Haynes cars. Whilst these cars were being tested the exhaust gas was so charged

with unconsumed carbon that it was found necessary to have a special exhaust pipe and fume blast to convey the fumes from the testing-room."

Something might be done certainly to prevent the occurrence of this nuisance in an aggravated form, by treating the waste gases in a condenser. All things considered, however, it seems very doubtful that oil engines, though they undoubtedly have their mission, will be largely used as a source of energy in the coming motor cars, but rather that the proper province of petroleum will be found to be as fuel for the generation of steam.

As examples of internal combustion or explosive engines and motor carriages in the market, the following may be taken as fairly representative of the most successful types, viz. :—Those of De La Vergne, Lewis, Panhard-Levassor, Daimler, Peugeot, Arnold, Benz, Lutzmann, Petter, Hill & Boll, Roger, Hertel, Haynes, Sintz, Mueller, the Duryea, Bollee, Pennington, Kane-Pennington, Roots, Roots-Venable, and the Britannia Company (Gibbon's patent). Whilst amongst the very numerous other types of combustion or explosive engines and motor carriages, which space does not admit of going into any lengthened description of, some mention may be made of the following :—The Pygmee, the Gnome (Seck's), Lepape's, Tenting's, Loyal's, the Gladiator (Darracq's), Dawson's, Maxim's, and Riotte's.

De La Vergne's Oil Engine Road Carriages.

The De La Vergne motor carriages (built by the De La Vergne Refrigerating Company) are made in

various sizes and of different types. Taking as an example a four-wheeled vehicle to seat two persons, it is fitted with a 4 horse-power gasoline engine, the cylinder and jacket of which is cast in one piece, and which is set to run at a speed of from 350 to 400 revolutions per minute. The exhaust is delivered into a muffler or exhaust box, by which the noise that would be otherwise made by it in escaping is more or less stifled or deadened. The unconsumed gas, moreover, passes into a condenser, whereby it is claimed to be disposed of without giving rise to unpleasant odours.

Electric ignition of the explosive mixture is employed. The tank and exploding or ignition battery are located beneath the front seat, and the tank is capable of containing a sufficient supply of gasoline to last for three days.

The engine and gearing are mounted on an iron frame, and are completely self-contained, so that the labour of fitting them in place in the carriage is considerably simplified. The total weight of the machinery is approximately 2 cwt. 3 qrs. About 3 lbs. of water are required per hour for cooling purposes in the cylinder jacket.

The power is communicated from the motor shaft to the driving wheel axle by means of sprocket wheels and pitch chains. The total weight of this carriage, including the above machinery, is about 9 cwt.

Lewis' Oil Engine Road Carriage.

The Lewis motor carriage is a single-seated four-wheeled vehicle, adapted to carry two persons. It is fitted with a 2 horse-power gasoline engine of a type invented by G. W. Lewis, which engine is exten-

sively used on launches and for other purposes. The motor consists of a single cylinder arranged vertically in a casing situated at the rear of the seat, electric ignition of the charges is used, and the electric current necessary for generating the igniting spark are provided by a small generator and battery. The gasoline tank and the reservoir for the cooling water are placed at the front of the frame, taking the place of the usual dash-board, the former holding sufficient for a run of 100 miles, and the latter 6 gallons.

The intermediate or sprocket wheel shaft is driven from the engine shaft by friction gear of raw hide, and is therefore perfectly noiseless in operation, both slow and high speed being provided, and the said speed being capable of being altered without interfering with the speed of the engine, which latter runs at from 300 to 500 revolutions per minute. Motion is transmitted from the intermediate or sprocket wheel shaft to the driving wheels by means of pitch chains, the proper distance between the said intermediate sprocket wheel shaft and the rear wheel axle being maintained by means of braces, which latter are adjustable as to length, thereby admitting of the tension of the driving chains being regulated.

The rear or driving wheels are 3 feet 8 inches in diameter, and the front steering wheels 2 feet 8 inches in diameter, and they are all constructed of wood with iron inner tyres and heavy solid rubber outer tyres or treads. The wheels are mounted in roller bearings of a special design, the fore or steering wheels having pivoted hubs, from which rods lead to a central vertical steering post or pillar, having a tiller or lever handle.

The weight of the above carriage is about 11 cwt., and the cost of fuel is stated to be about ½d. per horse-power per hour.

A double-seated carriage with the seats placed back to back, and capable of accommodating four passengers, has also been built by the same maker. This larger vehicle weighs about 13 cwt. 3 qrs., and is fitted with a 4 horse-power double cylinder engine, weighing about 4 cwt., and developing 6-brake horse-power.

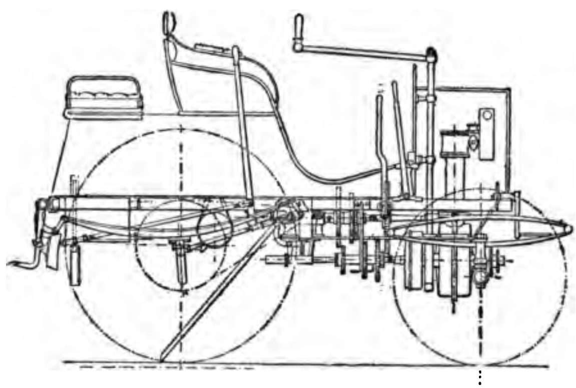

FIG. 20.—Panhard-Levassor Road Motor Car (Side Elevation).

Panhard-Levassor's (Daimler) Oil Engine Road Carriages.

As having divided the first prize in the Paris-Rouen competition with the Peugeot motor carriage, the Panhard-Levassor, and also the former, are worthy of very considerable attention, as being about the most successful carriages of this type that have been constructed up to the present time.

The running gear and body of the Panhard-Levassor carriage is illustrated in side elevation in Fig. 20, and Fig. 21 is a plan with the said body removed, from which it will be seen to consist of a frame mounted through suitable springs upon four wheels (shown in chain lines in the drawing), and supporting the motor mechanism, the said frame comprising both iron and wood members. The body of the carriage is, as shown in Fig. 19, arranged to seat four passengers, and is so secured, by means of four bolts, to the frame as to be both easily removable therefrom and to admit of

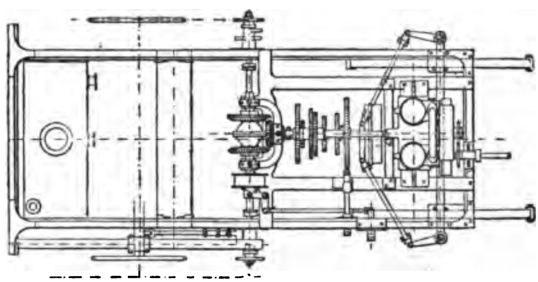

FIG. 21.—Panhard-Levassor Road Motor Car (Plan).

ready access being had to the mechanism for cleaning or repairs. The wheels provided upon this vehicle are usually of wood with flat iron tyres, but those of some of the carriages are fitted with iron tyres protected or cushioned with treads of indiarubber.

The engine employed for the production of the required horse-power is a Daimler benzoline motor of 3.7 horse-power. It has two cylinders, each 2.95 inches in diameter by 4.72 inches stroke, having their axes in the same plane, but converging so as to form between

them an angle of 15°. The downward stroke of one of the pistons corresponds to the upward stroke of the other, only one crank being provided on the shaft, which crank is formed of two discs which also act as a fly-wheel, and is enclosed in a box or casing and lubricated by the superfluous cylinder lubrication.

The principle upon which the Daimler oil motor works presents no novel features, the drawing in of the explosive mixture, the compression thereof, and the expulsion of the waste gases, being all carried out in a manner absolutely identical with that of the well-known "Otto cycle." The details of construction, however, especially the automatic arrangement for supplying the charge of oil required to form, in combination with the proper proportion of air, the explosive mixture, are very simple and effective, and the engine on the whole is undoubtedly one of the best of its class that has been designed up to the present time. The main features of construction are as follows :—The two cylinders are cast together, and the oil is conveyed to a suitable jet at a constant pressure, and vaporised at that point by the induced draught due to the suction action of the piston. The carburetted air passes into the cylinder freely through the admission valve until the piston reaches the termination of its stroke. On the return stroke of the piston the compression to which the gas is subjected is regulated by means of the strength of spring employed, and is generally between 42 and 56 lbs. The explosion takes place directly after compression has been effected, and as the piston is starting on its forward stroke. On the return or inward stroke of the piston, a discharge valve located opposite and

below the gas inlet valve in a trunk at right angles to each of the cylinders is opened by a rod operated by a cam upon a small shaft rotating at half the speed of the main shaft, and therefore lifting the said valve at every other revolution. The cylinders, as also the trunks fitted with the inlet and outlet or exhaust valves, are cooled by a water circulation, and the connecting rods and crank discs are, as above mentioned, enclosed in an air-tight casing, by which they are effectively protected from the access of dust and dirt or other foreign bodies. The shell or casing, moreover, being partly filled with the superfluous oil from the cylinders, ensures the perfect lubrication of the crank shaft, &c., and enables the high working speed of 700 revolutions per minute to be kept up without difficulty.

The explosive mixture is fired or ignited by means of platinum tubes, which are maintained in a state of incandescence by burners located beneath, which burners are supplied with spirit from the main reservoir when the latter is charged, and the contact is automatically effected by a reciprocating part of the engine.

The carburator for supplying explosive mixture to the cylinders was primarily constructed with a float arrangement for cutting off a determined constant supply from the main body of the gasoline. The air which is drawn in by the motor passes through this body of spirit, and passes to the cylinder through a three-way cock, by which the proportion of air added to the carburated mixture can be regulated. A fine wire gauze screen is also provided to arrest any liquid particles that otherwise might be carried over with the gases.

The cooling water for the cylinder jackets is stored

in a tank containing about 8 gallons, and the circulation is maintained by means of a centrifugal pump driven by a friction disc upon the driving shaft, a condenser being provided beneath the carriage for cooling purposes.

The engine runs normally, as already mentioned, at a speed of 700 revolutions per minute, but can be regulated by checking the exhaust so as to reduce the above within certain limits. A lever within easy reach of the driver admits of the shifting of the slide valve so as to modify the exhaust passage and slow down the engine.

The motor is located in the fore part of the carriage, which would appear to be an objectionable arrangement, for two reasons, viz., first, that the advantage of having the weight of the mechanism over the driving wheels is thus lost; and, secondly, that the disagreeable odours inseparable from the use of motors of this type would be far more apparent to the passengers than where the said motor is placed at the rear. So far, however, as efficiency is concerned, this position of the engine, which the designers consider to be the most advantageous possible, does not seem to be in any way detrimental.

Rotary motion is transmitted from the crank shaft of the engine to a second or intermediate shaft placed in line therewith, through a friction clutch, thereby admitting of the motor being started without at the same time putting the shaft carrying the driving gear in motion, and thus allowing of the power being transferred thereto slowly and without shock. This clutch consists of two parts, each comprising two cones mounted on the same axis, the outer one being at a

sharp angle and the inner one at an angle of 45°, and resting through springs on the support of the outer cone.

The driving gear admits of three different approximate rates of speed being obtained, viz., 4, 8, and 12 miles per hour. This is effected by means of a sleeve mounted upon the transmission shaft, and whilst free to move laterally thereon, forced to rotate therewith by a key or feather, and which sleeve, moreover, carries three toothed or spur wheels gearing or meshing with one or other of a set of different toothed or spur wheels mounted upon another shaft placed parallel with the said transmission shaft. A lever (the central one of the three shown in the drawing) allows of the manipulation of the sliding sleeve by the driver, the mechanism being so arranged that no change from one rate of speed to another can be effected until the toothed wheels are thrown entirely out of gear, and the driving and intermediate shafts disconnected.

The rotary motion of the driving shaft is transferred to the driving wheels by means of a bevel pinion gearing into bevel wheels mounted loosely upon a transverse intermediate or transmission motion shaft with an intermediate sleeve clutch, by moving which either to the right or to the left, by means of a suitable lever, the one or other of the bevel wheels can be caused to gear with the pinion, and the driving wheels be consequently moved to propel the vehicle in the one or other direction, through pitch chains which pass over grooved chain wheels on the rear axle, and over drums fixed on the extremities of the transverse shaft, the differential movement necessary to secure

independent action of the driving wheels being on the rear axle.

The rear axle in this carriage is fitted to revolve, being connected to the springs through axle boxes. The steering is on the Jeantaud divided axle system, which has been already described with reference to the Serpollet steam-carriage.*

The lever for operating the three-way cock, and regulating the admission and density of the carburated air to the cylinders of the engine, is placed conveniently opposite the driver. The reversing lever is on his right, and next to it is situated the speed regulating lever, the brake lever being located, also on the right, immediately beside his seat. A strap brake, which can be operated by a pedal lever, is also provided, and an arrangement whereby upon either brake being thrown into action the driving gear will be at the same time automatically thrown out of action by the disconnection of the clutch.

The weight of a carriage of the type shown in the illustrations, which is adapted to carry four passengers, is, when in working order, about 13 cwt. 3 qrs. A smaller carriage for two passengers only, but otherwise of the same type, weighs under similar conditions about 9 cwt. 3 qrs.

The management of the carriage, when everything is in order, is simplicity itself, all that should be required for starting being to light the burners and rotate the motor a few times through a crank provided in front of the carriage. The admission of carburated air

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* See pages 52, 53 for description and illustration of the Jeantaud steering gear.

having been then regulated, the machine will be ready to start in five minutes.

A stoppage will have to be made after every three or four hours run to inspect the mechanism, which, however, can be easily done, as it is enclosed in a box fitted with movable shutters admitting of easy access being had thereto on all sides; and also to renew the water for cooling the cylinders.

When stopping for any length of time the supply of carburated air must be cut off and the burners extinguished, and a small amount of petroleum should be inserted into each cylinder to prevent them from fouling.

The cost of working has been variously given. The consumption at the trials made in 1894 was estimated to be under a quart of spirit for every 7 miles travelled, and the cooling water used at about 2 gallons per hour. The makers state that the cost of running an average vehicle is not above one penny per mile.

In the later types of Panhard-Levassor carriages, similar to the one which made the best time in the race from Paris to Bordeaux and back, certain modifications have been introduced.

The improved two-seated carriage weighs about 12 cwt. 1 qr., and is fitted with a 3 horse-power nominal motor. The driving gear gives speeds of 4½, 10, and 15½ miles per hour.

The four-seated carriage has also a 3 horse-power nominal engine, but this carriage is only adapted to travel at speeds of 3¾, 7½, and 15 miles per hour.

The cylinders are, in both these later types of engines, placed parallel to each other, and the length of the strokes is increased to 5.51 inches. The engines

run at the high speed of 800 revolutions per minute, and they are each capable of developing 4 horse-power actual, and only weigh 1 cwt. 2½ qrs.

Important modifications have been likewise made in the carburator,* which is fitted with an automatic regulator. Two chambers are now provided, in the first of which the spirit is maintained at a uniform level, and the other one of which forms an air chamber and is connected up with the motor. From the bottom of the first or spirit chamber a pipe is led to the second or air chamber, and terminates at its vertically projecting end in a finely perforated nozzle, through which a thin jet of spirit is drawn into the air chamber at each stroke of the pistons, and the carburated air is then heated and delivered to the cylinders. By the regulation of the above-mentioned jet the degree of carburation to which the air is subjected can be readily and effectively adjusted.

The third longitudinal shaft is, moreover, now extended and carries at its extremity a bevel pinion capable of engaging with one or other of two bevel pinions, which latter are capable of being moved endways through the reversing lever. A deferential gear, shown in the plan view, Fig. 21, is also fitted to the latest types of carriages, the hind axle being fixed and rotary motion being transferred from the motor by a countershaft, at the extremities of which are sprocket or chain wheels connected through pitch chains with larger diametered sprocket or chain wheels bolted to the spokes of the driving wheels. The gearing is completely enclosed in and protected

* See also pages 84-88.

from dust, &c., by a casing not shown in the illustration.

The wheels are still constructed of wood, and are both fitted with iron tyres, and sometimes with iron tyres having outer indiarubber ones or treads.

The cooling water tank is located at the rear of the vehicle, and immediately below it is a waste-water tank.

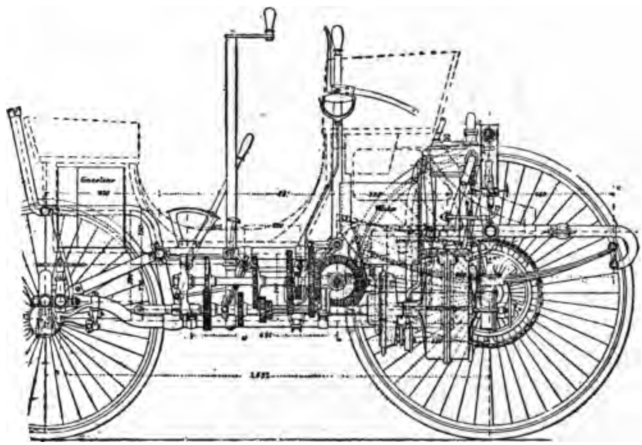

FIG. 22.—Peugeot Road Motor Carriage (Side Elevation).

A crutch, shown in the side elevation, Fig. 19, is hinged under the frame, and can be dropped, as in the drawing, to skid the vehicle when stopped upon a steep gradient.

Peugeot's (Daimler) Oil Engine Road Carriage.

The Peugeot road motor car, as having proved itself about equal in efficiency to the type just described, may next be appropriately mentioned.

Fig. 22 shows in side elevation a standard type of Peugeot carriage. The entire mechanism is mounted upon a frame supported upon the axles through plate springs having sufficient play to admit of their assuming a horizontal position.

A special feature of this frame is that it is constructed completely of cold drawn weldless steel tubes, the largest being 2.01 inches, and the smallest 1.61 inch in diameter, and the thickness of metal being .12 inch. The various members composing the frame are connected together by stamped or cast steel pieces and brazed joints, and the principal parts of the said frame are further strengthened by bracings of smaller tubes, or of bars of a V-shape in transverse section.

The wheels are of the cycle type, the spokes being of steel wire of from .20 inch to .24 inch in diameter, and so arranged that they can be easily tightened up when necessary or replaced in case of accident. The outside rims or felloes are grooved and fitted with strong solid vulcanised indiarubber tyres, and the bearings are of the ball variety.

As in the case of the Panhard-Levassor carriage, the Daimler type of motor has been hitherto employed to supply motive power for the Peugeot carriage, but it is said that in the later vehicles it is about to be replaced by a new gasoline motor that has been recently designed by M. Peugeot himself.

As has been already intimated, the most important part of the Daimler motor is the carburator, several forms of which are in use, and two of which are illustrated in vertical central section in Figs. 23 and 24. That shown in Fig. 23 is one of the earlier patterns, and comprises a receiving cylinder, a float, an indi-

cator or gauge for showing the level of the oil, a central oil supply pipe, suitable apertures for the admission of air and the discharge of the carburated mixture, a regulating cock or valve, and a wire gauze filter or strainer, all of which parts are very clearly indicated upon the drawing.

A rubber pipe connected from the main supply tank to the supply pipe of the carburator enables both the

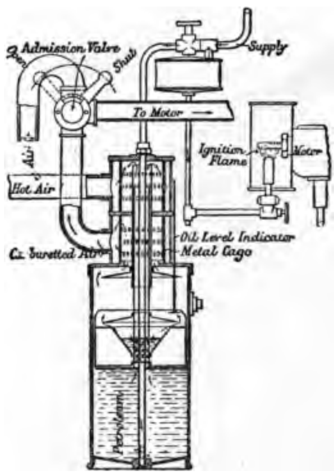

FIG. 23.—Daimler Carburator.

carburating chamber and the lamp reservoir to be filled, the overflow from the latter passing on to the former.

The manipulation of the driving mechanism, which is in this, as in that previously described, extremely simple, will be very readily understood by referring to the drawing. The motor, as has been already mentioned with regard to the Panhard-Levassor carriage,

is first turned by hand, through a suitable crank handle placed at the rear of the smaller cars and in front of the larger vehicles, and the suction action of the motor draws a supply of air, usually warmed by burners placed beneath the pipe, into the upper part of the carburator, which air, passing through the wire-gauze strainer, descends the central pipe and discharges through the perforations provided at its lower extremity. The carburised or carburated air then rises and is delivered into the bottom of the upper portion of the carburator, from whence it is conducted through a suitable pipe to the distributing chamber of the motor, a three-way valve upon this pipe regulating the admission of non-carburised air, in such a manner that the amount of carburised air passed in will be increased when that of non-carburated air is diminished, and the reverse. The path taken by the air is clearly indicated on the drawing by the arrows. The regulating valve is under the control of the driver through suitable levers, and micrometric screw gear.

One objection to the above-described form of carburator is, that the oil level therein is constantly varying, and no means are provided for its automatic renewal. As the gasoline in the reservoir, moreover, will not be completely consumed, the density of the residues would after a short time rise to such a height as to prevent the proper working of the engine, were not frequent recharging, and likewise withdrawal of the oil remaining in the bottom of the carburator resorted to.

The other type or carburator illustrated in Fig. 24 is preferably used in the Peugeot carriages. In this form the gasoline from the main reservoir enters the

carburator chamber or receiver from the bottom, passing first through a wire-gauze strainer and then through a small aperture, and filling the said chamber so as to cause the float shown therein to rise, and through the levers located in the upper part of the said chamber, and a conical-ended spindle, close the admission aperture and cut off the supply, at such time as the level of the oil is slightly above the top of the discharge nozzle in the carburating chamber. No

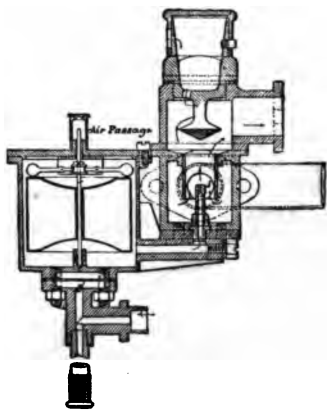

FIG. 24.—Daimler Carburator (Later Type).

discharge of oil will thus take place into the said carburating chamber until the motor has been started by hand as before, when the gasoline will be projected in a thin stream against a conical-shaped baffle, become vaporised by the current of heated air, and after being mixed with a sufficient supply of non-carburated air, conducted to the motor. The mixture can be regulated by the valve shown at the upper end of the carburating chamber; at starting the supply of

cold air is entirely stopped, and should the first explosion fail to take place, the carburating chamber should be heated by means of an asbestos torch steeped in gasoline.

This latter arrangement of carburator has, it is stated, given very satisfactory results in practice, and provided reasonable care be taken to maintain the parts clean, is said to be most reliable.

The explosions of the mixture in the motor are effected by a series of platinum points maintained constantly in a state of incandescence by means of burners, one form of which consists simply of a Bunsen burner, having a cotton, asbestos, or wire-gauze wick. The spirit rising by capillary attraction from a small aperture in the top of a central tube becomes mixed with a sufficiency of air before reaching the burner. The burner requires a preliminary heating before starting in order to secure volatilisation and prevent smoke, which latter would impede the proper heating of the ignition tube from being effected.

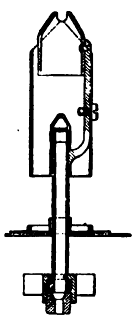

FIG. 25.
Longuemarre Gasoline Burner.

Fig. 25 shows a type of burner known as the Longuemarre burner, to which the gasoline is delivered under pressure, thereby obtaining additional efficiency and economy, at the expense, however, of a certain amount of increase in danger.

The motor employed in the carriage under consideration is of $2\frac{1}{2}$ horse-power, and its movements are transmitted to the wheels by an arrangement of gearing that will be readily understood by reference to Fig. 22.

It may be here remarked that originally the designers of this carriage employed both belt and friction gear, thinking not unnaturally that gearing of one of these types would present a feasible means of securing more control over the alteration of speeds, and would also admit of starting and stopping being effected more gradually. A short trial, however, sufficed to show them that owing to the very rapid wear of the working parts from unavoidable heating, and by reason of the great loss of power experienced in these methods of transmission, their use was inadmissible, and consequently recourse was had to toothed gearing.

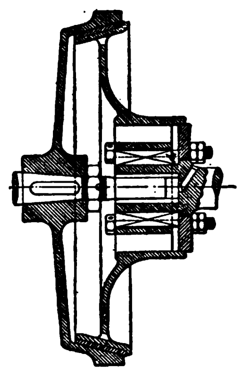

FIG. 26.—Peugeot Transmission Clutch.

The connection between the motor shaft and the transmission or intermediate shaft is effected, as in the case of the previous carriage, by means of a cone friction clutch, the pattern employed in the carriage under consideration being shown in vertical central section in Fig. 26, from which view its construction will be seen without further explanation.

This clutch when in gear communicates rotary motion to a square shaft placed in line with the engine shaft, and upon which four toothed wheels or pinions are mounted in regular order according to their size, so as to be forced to rotate with the said shaft, whilst free to move laterally thereon, the said latter movement being effected by means of a forked

lever, which can be conveniently operated by the driver. Another series of toothed or spur wheels is mounted upon a second transmission shaft, one or other set of those laterally movable being caused to mesh or engage with the latter, according to the speed desired. This second transmission shaft is connected to the intermediate driving shaft by bevel gearing, and the said shaft is provided with differential gear, and at either extremity with a chain or sprocket wheel coupled to

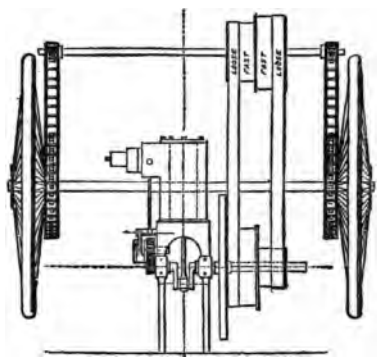

FIG. 27.—Arnold's (Benz) Oil Engine Road Carriage (Part Plan).

another chain or sprocket wheel upon the corresponding end of the driving axle by a suitable pitch or driving chain.

Arnold's (Benz) Oil Engine Road Carriage.

A carriage fitted with a Benz gasoline motor is that designed by Arnold, the rear axle and wheels of which, with the driving mechanism, are shown in Fig. 27. This vehicle is one adapted for two passengers, power being transmitted, as shown, from the motor shaft by

means of belt gearing to a second or intermediate motion or transmission shaft, from which latter rotary motion is communicated to the driving wheels in the usual manner through chain or sprocket wheels and pitch chains.

The Benz motor shown in Fig. 27 is in use upon several other cars, some of which will be subsequently briefly described. The single cycle Benz motor compresses the gas in the clearance at one end of the cylinder during the forward stroke of the piston, and ignition takes places by an electric spark located at the side of the said cylinder. On the other side of the piston the air that has filled that end of the cylinder is forced through a suitable aperture in a slide piece into a reservoir, the aperture or passage to the latter being closed up at the end of the stroke by the said slide, and the cylinder end opened to the atmosphere so as to admit of a fresh supply of air being sucked in during the obverse stroke of the piston. During this stroke, moreover, an exhaust opens and admits of the escape of the burnt gas, and at about half-stroke the opening of another valve allows the charge of air previously compressed in the reservoir to escape into the cylinder, so as to rush through the same, and out at the exhaust aperture, and thus to completely sweep out all the said gas. The above-mentioned valves then close, the fresh air still remaining in the cylinder is compressed, and petroleum vapour is injected through a valve automatically operated by a suitable lever, the explosive mixture thus formed being exploded at the beginning of the next stroke.

This is a very constant and powerful motor of its class, relatively to the size of the cylinder, but is

rendered very complicated and heavy by the number of parts required to work the above-mentioned valves.

The Otto-cycle Benz motor is much simpler in construction, the cylinder being open at the one end, and the slide and valve gear being rendered unnecessary, and only two tubes being required, viz., those for admission and exhaust.

Lutzmann's (Benz) Oil Engine Road Carriage.

Another carriage worked by means of a Benz gasoline motor * is that designed by F. Lutzmann. The engine shaft in this arrangement is connected to the second motor shaft by crossed belts, and power is transmitted from the latter to the driving axle by chain gearing.

The motor employed is of about 3 horse-power, and runs at about 500 revolutions per minute. The mechanism is enclosed in a box at the rear of the carriage, the water coolers being located at each side. The oil tanks are rectangular, and the exhaust stifle-box or silencer consists of a cylindrical-shaped box or casing.

The front wheels, which are used for steering, are of smaller diameter than the rear or driving wheels, and are mounted in forks, connected together by cranks and a connecting rod. The steering is effected from a vertical steering pillar, surmounted by a hand-wheel, through chain gearing.

Fig. 28 shows a motor van, also from the designs of

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* For description of this motor, see Arnold's carriage.

Mr Lutzman, which vehicle has been imported into this country by Messrs Julius Harvey & Co., a firm who have made motor cars one of their chief specialties.

FIG. 28.—Lutzmann Motor Van.

Petter, Hill, & Boll's Oil Engine Road Carriage.

The mechanism of Petter, Hill, & Boll's oil motor carriage is illustrated in Figs. 29 and 30. This carriage which is intended for two or four passengers, according to the gradients to be surmounted, is supported upon

four wheels, the rear or driving wheels being of comparatively large diameter, and the front wheels considerably smaller, and arranged for steering.

The motive power is supplied by an oil engine having a cast-iron cylinder 3½ inches in diameter by 6 inches stroke, and fitted with a light steel cooling water jacket. This cylinder is bolted to two steel bars placed parallel to each other, and also supporting

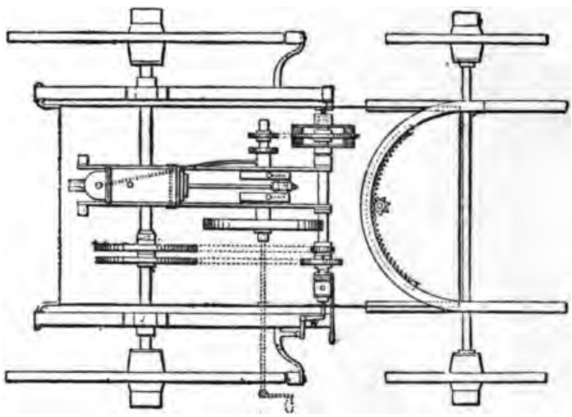

FIG. 29.—Petter, Hill, & Boll's Oil Motor Carriage (Plan).

the main bearings, the weight of the engine fly-wheel and side bars being about 1 cwt. 8 lbs. The crank shaft is balanced and is recessed for oil. Rotary motion is transmitted from the crank shaft to a first or intermediate motion or transmission shaft by chain gearing and a friction clutch operated by a lever, which locks, when desired, the chain or sprocket wheel upon the said first motion or intermediate shaft. Motion is communicated from the latter shaft to the

driving axle by two sets of chain wheels and chains for different speeds, that for the slow speed being fitted with a ratchet box. Another lever admits of the operation of the change of speed being effected, and when the higher speed is in use the slow speed will, owing to the above-mentioned ratchet box, be enabled to overrun. The reverse movement of the starting lever, besides throwing the clutch out of gear and disengaging the first motion shaft from the engine, also applies the brake, which is more clearly shown in Fig. 30. The arrangement of the above-mentioned parts, as also that of the steering, which latter is effected by means of a toothed quadrant and pinion, will be readily understood from the illustrations. The water and oil tanks are both located at the rear beneath the back seat.

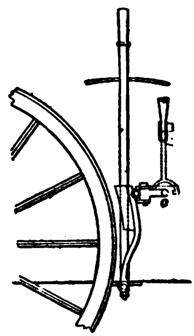

FIG. 30.—Petter, Hill, & Boll's Starting Gear and Brake.

The weight of the carriage in running order, with supplies of water and oil, is about 9 cwt. With two passengers on board a speed of 10 miles an hour on level roads is said to be attainable, and any reasonably steep gradients to be easily surmountable. On level roads and slight gradients the carriage will readily carry four passengers.

Roger's (Benz) Oil Engine Road Carriages.

The Roger carriage is a four-wheeled vehicle of the park phaeton type, which is also fitted with a Benz

gasoline motor.* It has wire wheels, and is adapted to accommodate two passengers.

A goods delivery waggon has also been designed by Roger, which is likewise fitted with a Benz motor, and is intended chiefly for city work. The engine used in the latter vehicle weighs about 5 cwt. 2 qrs., the waggon itself about 1 ton 2 qrs., and it has a carrying capacity of about 11 cwt. 2½ qrs. It has sufficient storage capacity to contain a supply of rectified petroleum for a run of 75 miles.

Hertel's Oil Engine Road Carriage.

The Hertel carriage is a somewhat peculiar-looking vehicle, with a single seat adapted to accommodate two persons. It has a tubular frame, and is supported upon four cycle pattern wheels, running on ball bearings and having pneumatic tyres, the front wheels being 28 inches and the hind wheels 34 inches in diameter. The front wheels are each mounted in a fork, one of which latter is pivoted at either side of the fore part of the carriage, and the steering is effected by suitable levers connected with the said forks.

This carriage is propelled by a two-cylinder gasoline engine, and is very light, weighing only about 2 cwt. when in running order. There are, however, no special features in the oil motor employed calling for particular notice.

Haynes' (Sintz) Oil Engine Road Carriage.

The Haynes carriage is also a single-seated one for two passengers. It is mounted upon four 28-inch

* See pages 91, 92 for description of this motor.

cycle pattern wheels, fitted with 1½-inch solid india-rubber tyres.

Propulsion is effected by means of a 2 horse-power gasoline engine of the type made by the Sintz Gas Engine Company. The special features of this engine are as follows:—The gas and air are mixed in the lower or one end of the cylinder, which latter opens into a chamber containing the crank sweep, and the said explosive mixture of gas and air next passes to the closed upper or other end of the said cylinder by way of a port, which is opened as soon as the piston, which is of the plunger type, reaches the bottom of the stroke. The mixture is compressed during the upward or inward stroke of the piston into the clearance space above the latter, being exploded by an electric spark at the moment that the said piston reaches the termination of the said upward or inward stroke, and is about to descend. The gas generator or carburator contains about 1 pint of gasoline, the feed being regulated by an automatic needle valve. Motive power is transmitted from the engine crank shaft to an intermediate transmission or motor shaft by means of sprocket or chain wheels and pitch chains, and from this intermediate transmission shaft to the rear or driving wheels by other sprocket or chain wheels and pitch chains.

The weight of this carriage in running order is about 9 cwt. 1½ qr., and the highest speed attainable is stated to be about 10 miles an hour. One charge of gasoline (1 pint) will enable about 50 miles to be run at ordinary speed.

A larger carriage of the same type, adapted to seat four persons, has 36-inch cycle pattern wheels, having

2-inch pneumatic tyres, and is fitted with a gasoline engine of 4 horse-power of the double-acting balanced pattern, constructed by Haynes & Apperson. The rotary motion of this engine is transmitted to the driving wheels in a similar manner to that above described. This carriage weighs in running order considerably more than the single-seated vehicle for two passengers.

Mueller's (Benz) Oil Engine Road Carriage.

The Mueller gasoline carriage was the one which made the best time at the Chicago competition in 1895, next to the Duryea motor carriage, which latter will be next described. The carriage under consideration was a four-wheeled one of the *vis-a-vis* type, the front wheels being the smallest, and used for steering purposes, and the mechanism being enclosed in a box or casing located directly over the rear wheels, which are of larger diameter, and employed for driving purposes. The motive power is, as in the case of the Roger carriage, a Benz gasoline motor.*

Duryea Oil Engine Road Carriage.

The Duryea gasoline carriage is likewise one of American design, and comprises several novel and interesting arrangements of parts, especially with relation to the motor employed.

The vehicle used in the Chicago race weighed about 6 cwt. 1 qr., had an engine giving a motive power of 4 horse-power, whilst weighing only a few pounds over

* For description of this motor, see pages 91, 92.

1 cwt., and possessed storage capacity for 8 gallons of gasoline. It is said to be capable of attaining a speed of 20 miles an hour on good roads.

The chief parts of the Duryea car, however, which are worthy of special notice, are the motor and carburator. Instead of taking place, as is most usual in engines of this type, in the cylinder itself, the explosions are effected in a separate chamber or compartment, which forms a reservoir, from which gas under pressure is supplied to the working cylinder.

The action is briefly as follows:—The gasoline is stored in a suitable tank or receptacle, from which it is delivered to, and passes through a pipe, having a branch at its lower end, into a large tube or cylinder, wherein it is vaporised by the action of heat. From this vaporiser the gas or vapour is conducted by a suitable tube to a burner having a tube discharging into a reservoir, and drawing in by induction sufficient air during its passage through this tube to admit of combustion. Equilibrium in the system, and the proper flow of the gasoline from the storage tank, is ensured by connecting the upper part of the last-named tank with the reservoir for receiving the mixed air and gas or vapour. This connecting pipe is fitted with a conical valve, the position of which can be regulated so as to control the supply of gasoline. A second valve allows of the pipe being entirely closed when the motor is stopped. The preliminary heating of the vaporiser is effected by means of a lamp, which likewise causes the ignition of the mixture as it enters the reservoir. The proportion of air mixed with the gasoline vapour is regulated so as to be about ten times as much in bulk as that of the said vapour;

and it may here be noted that the greater the volume of air taken over, the lower will be the temperature of the mixture resulting from combustion, and the less necessity will there exist for the maintenance of a circulation of cooling water round the cylinder. The pressure of gas obtained in the reservoir and in the pipe is about 120 lbs. per square inch. The engine is set in motion by means of a starting lever, and it is hung or suspended from the frame of the vehicle.

Motion is transmitted to the two rear or driving wheels by means of spur or toothed wheels, and a pinion, keyed upon an intermediate shaft, working the differential gearing, the shaft of which latter is mounted upon two springs bearing upon the frame of the vehicle.

The steering of the car is effected by a very simple arrangement, comprising a lever and two rods, the wheels being mounted upon the divided axle principle. The fore carriage is hung on a transverse spring, thereby enabling it to turn on a trunnion, and admitting of the front wheels traversing or passing over very rough surfaces without straining the frame of the carriage. The pivots of the wheels also are placed at an inclination to the vertical, which is found both to facilitate the steering, and to prevent the said wheels from being suddenly jerked out of their course by obstructions.

The car is fitted with four different speeds. The change from one speed to another is effected by means of a catch fitting into notches on the steering handle, which catch is connected through a cord passing down the steering column, and over suitable guide wheels, to a pulley mounted upon a shaft carrying

four cams. According as this pulley is rotated through a greater or less angle by the above-mentioned cord and catch, one or other of these cams will be caused to stretch, and render operative, one or other of four belts or bands connecting the driving shaft with the intermediate shaft, and giving different speeds thereto. Reversing is likewise effected by the same means.

Bollee's Oil Engine Road Carriage.

Figs. 31, 32, 33, 34, and 35 illustrate the motor carriage designed by Léon Bollée, a French inventor.

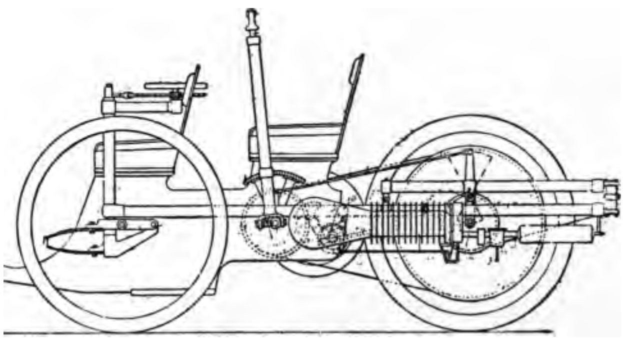

FIG. 31.—Bollée Road Motor Car (Side Elevation).

Mr Bollée's improvements relate to the following parts, viz., the frame, the motor, the transmission gear, the mechanism for engaging and disengaging the motor, for changing the speed, and to the brake and the mechanism for actuating the latter.

As regards the frame. This consists of a ladder-like structure, comprising two longitudinal tubes connected by three cross pieces. At the two extremities of the front cross-bar are arranged two vertical sleeves, which serve to support the pivots of two steering

wheels, each of which is capable of turning round its pivot point sufficiently to enable its axis to cross the rear axle in the well-known manner. On the upper end of the right-hand sleeve is a horizontal tube supporting the steering hand wheel. On the lower end of each pivot is a steel bracket, to which is hinged the bracket of the axle of the corresponding wheel, the free ends of the latter bracket being connected by means of two connected springs to the end of the

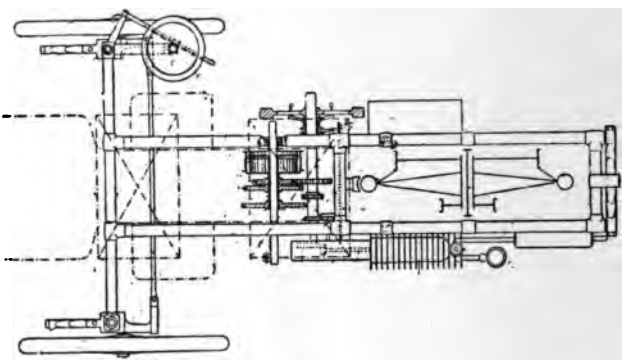

FIG. 32.—Bollée Road Motor Car (Plan).

former bracket. The same arrangement is applied to the other steering wheel, and enables springs to be employed without necessitating the use of an oscillating axle, with the springs placed transversely to the vehicle.

The rear axle is secured beneath a horizontal support made out of a U-shaped piece of steel tube, which is hinged by the ends of its parallel sides on to the longitudinal tubes of the frame. At its opposite extremity is a cross piece connected to the frame by

means of two combined springs, which tend to maintain the said U-shaped support and the vehicle frame at a desired normal distance apart. The rear axle is supported at each end in spring hangers hinged or jointed to the tubes of the frame. This arrangement ensures the movements of the axle, under the action of shocks to the vehicle from passing over uneven surfaces and obstructions, being parallel to itself.

The seats, which are of the char-a-banc type, are

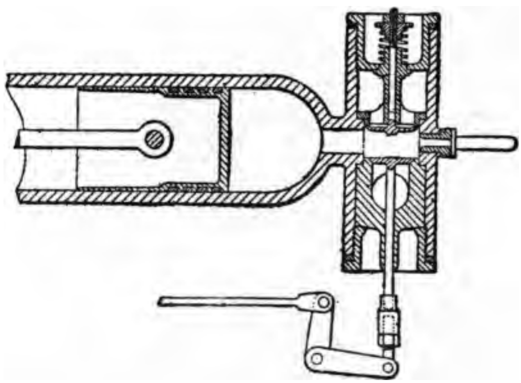

FIG. 33.—Bollée Admission and Exhaust Valve for Internal Combustion Engines.

arranged the one behind the other on a small box made preferably of sheet-iron, which box is extended in a forward direction to form a footboard or support for the feet of the front passenger, suitable feet supports being provided at each side of the box for the rear passenger.

The motor has a cylinder fitted with wings or gills for cooling purposes, but a water circulation is some-

times used instead. At its rear end is a cylindrical casing, shown more clearly in the enlarged sectional view, Fig. 33, in which work the admission and exhaust valve, the seats for which are secured in place by means of screws, or bolts and nuts, thus enabling the valves to be readily removed for cleaning purposes without having to take off the tubes corresponding to the admission and exhaust apertures in the wall of the cylinder. The ignition of the charge

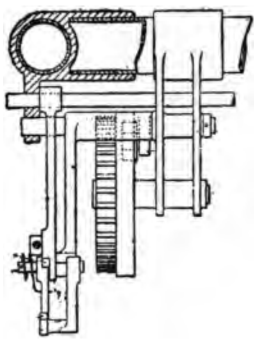

FIG. 34.—Bollée Governing Arrangement for Internal Combustion Engines (Front View).

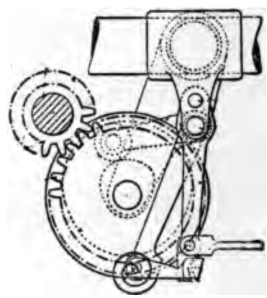

FIG. 35.—Bollée Governing Arrangement for Internal Combustion Engines (Side View).

of gas in the cylinder is effected either by an electric ignition plug or by incandescence. The exhaust valve is actuated by a spindle, the length of which can be adjusted, and which spindle is so connected through levers and links, shown in Figs. 34 and 35, which represent respectively a front and side view of the said mechanism drawn to the same scale as Fig. 33, with a governor combined with the fly-wheel, that the motor

will be precluded thereby from exceeding a certain predetermined speed. When the governor opens, it moves this rod into the position shown in Fig. 34, and the mechanism is such that the exhaust valve will remain at rest. On the closing of the governor, however, the said rod is withdrawn, and the deposition of the parts will then be such as to admit of the operation of the exhaust valve being effected.

The main features of the transmission mechanism consist in the arrangement of intermediate gears, movable laterally, in combination with a pulley rotable with the former, but not free to move in a lateral direction. Transmission of power to a large pulley fixed on one of these driving wheels which is made by belt gearings ; and of engaging and disengaging mechanism, produced by the alternate stretching or the slackening of a belt due to the forward or backward movement of one of two parallel shafts, viz., the rear axle.

The steering hand-wheel is supported by the sleeve of the pivot of one of the wheels, to which pivot it is directly connected by a chain gear.

The brakes consist of a shoe fixed to a cross-bar on the frame, and a drum keyed to the boss of one of the wheels, and which drum is encircled by a leather-lined steel band, the two ends of which are attached to the frame. Upon the axle being moved in the one direction, the tyre of the wheel will rub against the said shoe, and the strap be likewise tightened upon the drum.

To render the driving of the car as easy as possible, a single lever is arranged to operate all the movements of throwing in and out of gear, changing the speed, and applying the brake.

Pennington's Oil Engine Road Carriage.

Figs. 36, 37, and 38 illustrate the improved internal combustion or explosive engine designed by E. J. Pennington, an American inventor, which forms the main feature of his motor carriage.

The most important points of novelty claimed to be possessed by this engine are—first, the provision of means whereby the initial charge of oil admitted to the cylinder at the starting of the engine will be

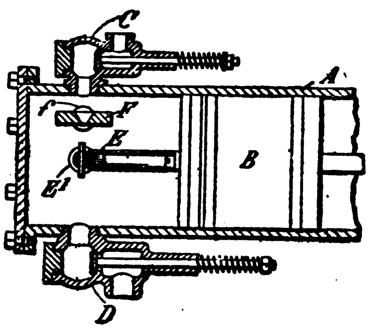

FIG. 36.—Pennington's Internal Combustion Engine for Heavy Oils (Longitudinal Section).

volatilised on entrance into the said cylinder, thus admitting of the use of charges of heavy oil, and the instantaneous starting of the engine even when the cylinder is in a very cold condition; second, an improved means for igniting the charges admitted to the cylinder of the engine by an electrically heated body.

Referring to Figs. 36 and 37, which illustrate in longitudinal and transverse section an arrangement adapted for heating charges of heavy oils, A is

the cylinder; B the piston; C an inlet valve through which the explosive charges enter the cylinder; D an exhaust valve through which the products of combustion escape from the cylinder; and E a movable electric ignition device carried by the piston, and operating in conjunction with a fixed electric contact E^1 carried by the cylinder A, and insulated therefrom. The exhaust valve D may be operated by any suitable device actuated by some moving part of the engine.

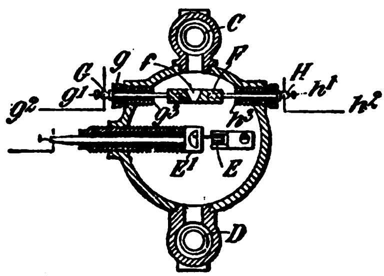

FIG. 37.—Pennington's Internal Combustion Engine for Heavy Oils (Transverse Section).

F is a body of pumice, lava, or other suitable material that is a poor conductor of electricity. This body is preferably made in the form of a plate or disc having an aperture *f* therein. The said body is located within the cylinder A in proximity to the inlet valve C, so that the oil charges that are admitted to the cylinder come directly in contact with the said plate or disc. G and H (Fig. 37) are two insulated terminals which are carried by screw sockets *g* passing through the walls of the cylinder A. The aforesaid terminals G, H, communicate at their inner ends with

the plate or disc F within the cylinder, and their outer ends are provided with binding screws g^1, h^1 for enabling electric conductors g^2, h^2 to be electrically connected thereto. These conductors lead from any convenient source of electric supply. The interiors of the said sockets g are provided with asbestos, or other suitable material, as indicated at g^3, h^3 for insulating the terminals G and H from the cylinder.

When an electric current is allowed to pass between the terminals G, H, the plate or disc F becomes incandescent, or sufficiently heated, to immediately volatilise the charge of oil as it enters the cylinder, and enables the said charge to be exploded by the electric ignition device E E^1.

After the cylinder has become heated by the successive explosions of the charges, the passage of the electric current between the terminals G, H may be stopped, and the engine then goes on working in the ordinary manner by the action of the electric ignition device alone. If desired, however, the body F may itself be used for ignition purposes.

This arrangement admits of the engine starting working immediately the charges of heavy oil are admitted thereto, without the assistance of any external means such as are generally employed for this purpose, and without the preliminary injection of lighter oil into the cylinder, as the heated plate or disc F effectually volatilises the oil admitted into the cylinder and ensures the immediate explosion thereof.

Instead of employing the two insulated terminals G, H, both of which extend through the walls of the cylinder A, one insulated terminal only may be used, the other terminal being connected to the cylinder

without extending to the outside thereof. In this case one of the electric conductors would be in electric connection with the outside of the cylinder, and only one aperture would then have to be formed in the cylinder for the reception of the other terminal.

Another arrangement, shown in Fig. 38, serves both for volatilising the oil and for ignition purposes. If charges of vapours or gases are used instead of oil for working the engine, this arrangement is then employed for ignition purposes only.

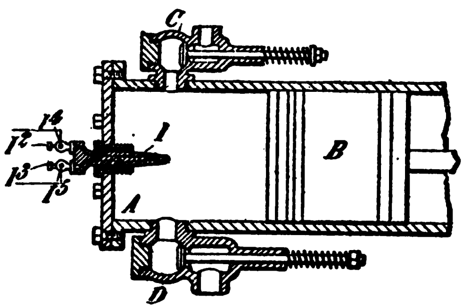

FIG. 38.—Pennington's Internal Combustion Engine, with Combined Arrangement for the Volatilisation of the Oil and for Ignition Purposes.

I is a rod, pencil, or other suitably shaped body of pumice, lava, or other appropriate material which extends through the cylinder cover, and preferably projects into the cylinder a sufficient distance to bring its inner end below the inlet valve C. This rod or pencil I is insulated from the cylinder cover by a screw socket, having a lining of asbestos or other insulating material interposed between the rod or pencil I and the said socket. I^2, I^3 are binding screws connected to the outer end of the rod or pencil for receiving and

holding the electric conductors I^4, I^5. Instead, however, of constructing the body I in the form of a rod or pencil, it is sometimes made of tubular or other shape.

Figs. 39 and 40 illustrate in plan and end view a recent pattern of the Kane-Pennington gasoline engine. Much that is eulogistic has been recently said about this motor, and much, it must be admitted, that requires more faith to believe than the writer can

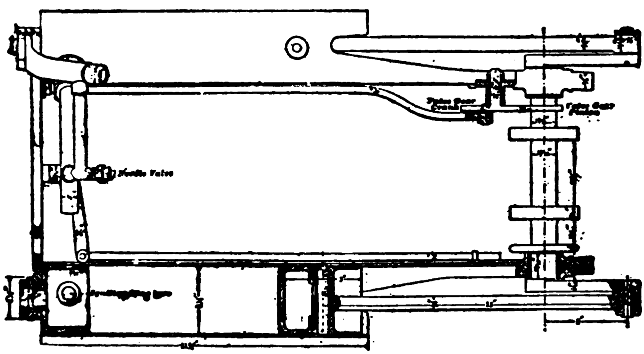

FIG. 39.—Kane-Pennington Gasoline or Explosive Engine (Plan).

lay claim to possess. However, in view of all that has been from time to time stated in the English technical journals, the following extended extract from the *American Machinist*, referring to the motor illustrated in Figs. 39 and 40, will be of interest, as emanating from the pen of an engineer (Mr Randol) who had fully inspected the carriages fitted with these engines in the early part of this year (1896):—

" In some way, so far wholly unexplained, the great heat which in other explosive engines manifests itself

as an inconvenient by-product, to be taken care of as best it may, is in the Pennington engine transformed into useful effect on the piston. I know that when the long, thin first spark is not put through the charge the engine becomes weak and hot, and that when this first long, thin spark, this 'mingling' or 'ripening' spark, as Mr Pennington calls it, is used, a common gas-engine, with its carburetter eliminated, gives twice its ordinary effect on the crank. I know also that all the experts who have been employed by capitalists to examine this engine have been first incredulous and then amazed, and finally enthusiastic, and I have therefore decided to let this first paper stand as it is, because it correctly exhibits not only my own experience, but the experience of all others, both learned and simple, upon a first examination of the motor.

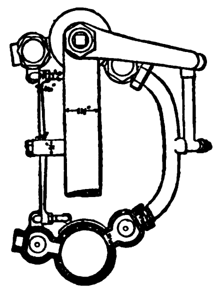

FIG. 40.—Kane-Pennington Gasoline or Explosive Engine (End View).

"This two-spark mechanism of the Pennington motor actually does not cost 5 cents, and yet when applied to the 'Regan' gas-engine, largely built up to the present time by the Kane establishment at Racine, it doubles the power of that motor. It is in the igniter, and in the double spark, or rather in the effect of the first spark, apparently, that the efficiency of the Pennington motor lies. In the Victoria,* the motive

* Motor car fitted with Pennington engine, entered at the Chicago competition.

power is chain geared, with two reductions, first to an intermediate shaft, then to a variable speed shaft, and last, from the variable speed shaft back to the drivers, each wheel being independently driven, as there is no through shaft for either the rear or front wheels, the Victoria design being on strictly bicycle construction lines. The reduction from the engines to the driving wheels is 4 to 1 for the slow speed, and 2 to 1 for the quick speed. An upright hand lever has three positions: standing upright, the engines are disconnected from the driving wheels; hand lever to the right gives 4 to 1 reduction to drivers; hand lever to left gives the quick drive, which is a 2 to 1 reduction from the motors to the drivers.

"The Victoria engines have a fly-wheel, and the right-hand crank wrist is prolonged to form a handle; the intermediate shaft sprocket wheel is loose, and may be clutched to the shaft by moving the upright lever. When not clutched to the shaft, the engines run without moving the vehicle. To start the engines, one complete turn to the engine shaft is made by hand, and it then continues to run from the action of the engines until either the oil or the spark-producing current is shut off. After the one revolution by hand, the riders mount the seat, and a movement of the vertical lever clutches the sprocket to the variable speed intermediate shaft, and the Victoria at once begins to move.

"The consumption of common kerosene oil per hour per horse-power indicated is about one-tenth of 1 gallon, or about 2 quarts per hour for 4¾ horse-power. Pennington's 2 horse-power motor weighs 17½ lbs., and his entire Victoria weighs less than 400

lbs., of which perhaps 140 or 150 lbs. belong to the motive power of reducing gear. It will easily transport a load of 800 lbs., making a total weight of 1,200 lbs.

"It will be observed that the cylinder proportions of the engine are not at all those common to gas-engines—2½-inch cylinder diameter by 6-inch stroke forms the standard unit. But a much greater digression is shown in an engine now under test, having a 2½-inch diameter with 12-inch stroke single cylinder, in which the terminal pressure is reduced almost to atmosphere, with a fuel gain of about 45 per cent. over the 2½-inch by 6-inch cylinder dimensions.

"Referring to Figs. 39 and 40, there is next to nothing in the way of description or explanation to give. The oil admission is simply a screw-controlled needle valve, which is very simple, and gives no hint of its two-current refrigerating powers. The cylinders are made of steel tubes, ground inside in a primitive engine lathe, and steady rest rig, dry, and almost certainly not a very close approximation to a cylindrical form. The pistons, I was told, were drop forgings. They would be more easily made in grey iron. The piston rings are grey iron, less than $\frac{1}{16}$ inch thick, with halved joining. The pistons and open cylinders appeared to be wholly free from any deposit, and were bright and clean. The trunk pistons are a very slack fit in the cylinders, perhaps $\frac{1}{32}$ inch small. The workmanship generally was fair, and the designing was specialised with a very high degree of ingenuity, as I need not say when it is remembered that a 58-lb. locomotive-motor bicycle made a mile in fifty-eight seconds on a street pavement.

"The passenger on the bicycle feels the impulse of each stroke of the engines, just the same as on a little stern-wheel steamer. Aboard the Victoria the heavy fly-wheel equalises the motion, and the individual piston impulses are not distinguishable. The kerosene is carried in a long tube on the top of the dashboard, and passes through the tubular framing of the body to the motors. The motors themselves are of the four-stroke cycle variety, and make one outboard working stroke and one inboard, idle, cylinder-clearing stroke, then an outboard charging stroke and an inboard charge-compressing stroke in sequence; the valve operating crank is driven by a pinion and spur 2 to 1 reducing gear on one side, with a cross lever transfer to the other cylinder. With the 6-inch stroke cylinder the exhaust is very audible, though not disagreeably so. With the 12-inch stroke cylinder the noise of the exhaust is not noticeable. There is no visible discharge of vapour, and no evident odour except in case of an over admission of oil; and an over admission of oil leads to an immediate loss of efficiency, which makes its continuance an impossibility.

"The one great mystery is the coolness of the naked cylinders, which should be red-hot at the end of the first twenty strokes or so of a run. Chemists are familiar with the establishment of low temperature pressures, but pressures established by explosion are not cold, as a rule, and the gas-engine has always been hot.

"The Kane-Pennington shops are making or have made general trials of the water-jacketed cylinder. The 2½-inch by 12-inch expansion engine is jacketed

and piped with top and bottom natural circulation pipes to a small water tank, which a run of some length did not seem to heat very much. The cylinders run perfectly well naked, with no cooling element more than their inevitable exposure to the atmosphere. There is evidently some heat-absorbing, or diverting, or abstracting element or operation in the Kane-Pennington engine not commonly present in the gas-engine, and it is difficult to see what this can be, if it is not the truth that the heat of the cylinder walls is absorbed by the incoming charge previous to the moment of the ignition, or else transformed into work on the piston, as it seems impossible that the gases after ignition should be otherwise than very hot indeed."

Roots' Oil Engine Road Carriage.

The main feature of Roots' motor carriage is likewise, as in the preceding case, in the form of engine employed, and as some interesting improvements in internal combustion or explosive engines have been made by Mr J. Roots, a gentleman who has devoted considerable attention to this subject, we purpose going rather fully into the matter.

In Figs. 41 to 44 are shown an oil engine, the arrangement of which exhibits the following special features :—

The crank is entirely enclosed in a box or casing attached to and forming part of, or fitting air-tight upon, the cylinder. When the explosion takes place on the working side of the piston, driving it forward, the other side of the piston compresses air into the

crank box, from which it is forced through the air-heater, which is closed to retain the pressure, and which has vertical or annular channels; is then mixed with oil and passed through the vaporiser, and thence admitted by the admission valve to the cylinder on the working side of the piston, where it is ignited by

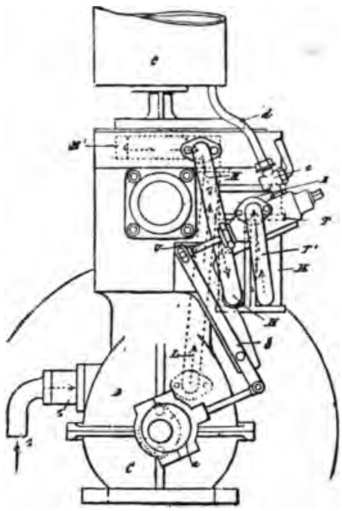

FIG. 41.—Roots' Petroleum or Explosive Engine (Elevation).

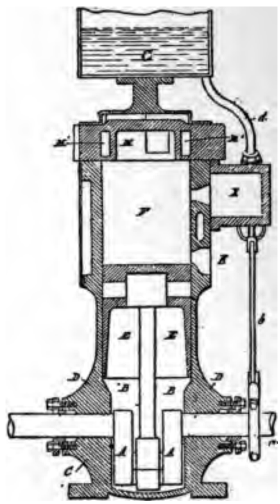

FIG. 42.—Roots' Petroleum or Explosive Engine (Vertical Central Section).

a hot tube. The air is sometimes passed through a channel in the cover to heat it, and a part of the air supply unheated is caused to enter the admission valve first, to prevent premature ignition.

The power of the motor is transmitted to the axle or spindle of the driving wheel by means of speed-reducing gear wheels. The water from the cylinder

jacket is passed through a number of tubes or through the tubular frame of the machine to cool it.

Another improvement is that the governor operates an oscillating lever fitted on a lengthened spindle, and a projecting part of the same lever, or a second lever attached to the same spindle, is thus thrust in the way of the oil feeder, so preventing the delivery of oil, and at the same time another or the same lever on the spindle is brought in front of a boss on the exhaust spindle, and prevents its closing, so that when the oil is cut off, exhaust products are drawn into the cylinder instead of air, and the cylinder thus loses less heat.

By the combination with the above of a second explosion chamber not only is an increased economy, but also a rapid and sudden increase of compression during the last small portion of the compression stroke obtained. In the case of small engines, this second chamber is cast like a pocket in the cylinder wall, and the charge is not drawn through it.

In the illustrations, A is the crank, B the crank chamber, C the crank pit, D an extension upon the cylinder, E the piston, F the cylinder, G the air inlet pipe, H the air heater, I the vaporiser or carburator, L a pipe and M^1 a channel conducting the air to the former, J the discharge valve from the vaporiser, K the exhaust port from the cylinder.

The air as it passes from the chamber B is forced up the pipe L, and becomes heated by its passage through the channel M^1 (Fig. 42) around the combustion chamber M on its way to and down a pipe N to the lower part of the air heater H, which is vertically divided into four or more channels P, P^1, P^2, P^3 (Fig.

44). The webs Q, Q^1, Q^2 are cut out alternately at the top and bottom of same to admit of the air as it issues from the inlet pipe N traversing all the channels successively; that is to say, up the channel P, over the web Q, down channel P^1, under channel Q^1, the orifice of which latter is shown at R in Fig. 43; thence up the

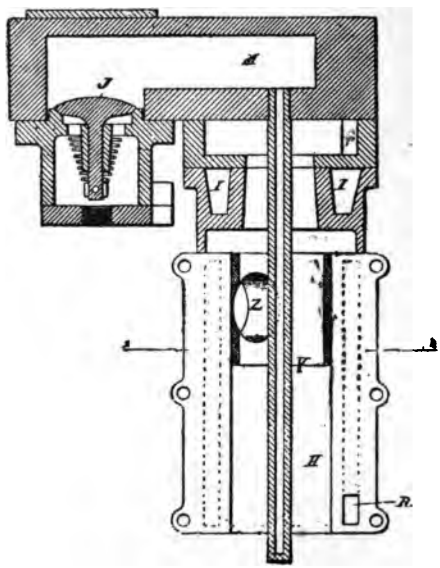

FIG. 43.—Roots' Air Heater for Petroleum or Explosive Engine.

channel P^2, over the web Q^2, down the channel P^3, from which in its now highly heated condition it is conducted through the oil feeder T by the pipe T^1 to sweep off the oil from the groove or grooves of the spindle U, and carry same into the vaporiser I for further heating and mixing before passing into the cylinder F through a suitable pipe and inlet valve J, where, upon

the return stroke of the piston E, it is compressed into the auxiliary chamber X and the combustion chamber M to be ignited by the hot tube Y, which is maintained at a sufficient heat by a lamp flame through the orifice Z, the same flame serving also to heat the air channel P, P^1, P^2, P^3 and vaporiser for the purpose before described.

The oil feeder is operated by the eccentric *a* and rocking lever *b*, the oil as it is used being supplied from the tank *c* by the pipe *d*, and shut off cock *e* (Fig. 41).

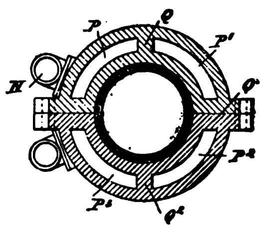

FIG. 44.—View showing Horizontal Section on line 1-2, Fig. 43.

In applying this engine to a vehicle such as the tricycle shown in Figs. 45 and 46, the tubular members *f*, *g* of the machine framing are arranged to serve as flow and return pipes respectively between the water tank *h* and jacket *i* of the engine cylinder, the engine itself being also supported from the cross frame *j* by the arms *k*, *k*, attached to the crank chamber and brackets *l*, *l* (Fig. 45) of the said cross frame *j*.

The power of the engine is transmitted to the driving axle of the vehicle by means of reducing gear consisting of a bevel pinion *m*, and a larger bevel wheel *n*, which latter is so arranged upon the driving axle with the friction clutch *z* (Fig. 46) that it may run loose upon it, when it is desired to stop the machine, or when going down hill, without necessarily stopping the engine; but when the power of the

engine is to be communicated to the driving axle, said bevel wheel *n* transfers its motion by means of the friction clutch *z* through the balance gear to the said driving axle of the machine, and is under the

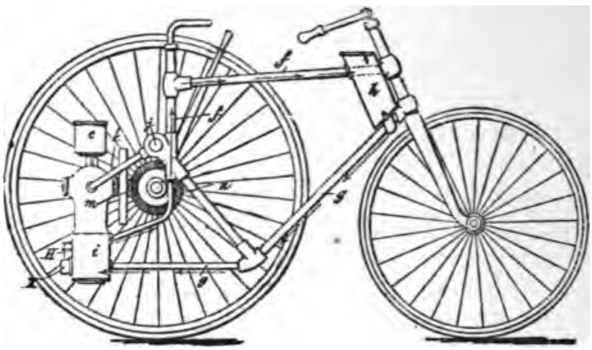

FIG. 45.—Roots' Petroleum Motor Tricycle (Elevation).

control of the driver by the lever *p*. The usual chain and treadle motion may be added when desired, so as to admit of the machine being propelled either solely

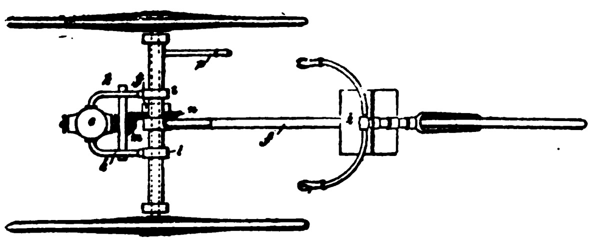

FIG. 46.—Roots' Petroleum Motor Tricycle (Plan).

by foot-power, or the latter being used as an auxiliary to the motor for hill climbing or on bad roads.

An improved governor for controlling the speed of the engine consists, as shown in Fig. 47, of an oscillat-

ing lever *q*, fitted on the lengthened spindle *r*, under the direct control of the governor *w*, in such a manner that when the maximum speed for which the governor is adjusted is attained, a projecting part *s* of the said lever *q* will be interposed behind a boss *t* on the exhaust

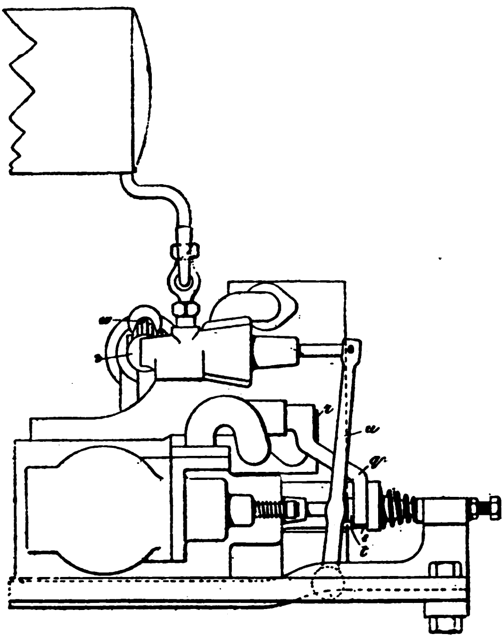

FIG. 47.—Roots' Governor for Petroleum or Explosive Engines.

valve spindle, having a hardened edge, and so prevent it from closing. The said boss *t* on the exhaust valve spindle also being in the way of the oil lever feeder *u*, will prevent the delivery of oil by arresting the outward motion of the groove on the oil feeder spindle toward the air passage.

From the above it will be seen that as the oil feed motion is simultaneous with the closing of the exhaust valve, the prevention of the latter from closing also prevents the action of the oil feed spindle, and as the exhaust valve is kept open during the suction stroke of the piston, the hot products of the previous explosion are drawn into the cylinder instead of air, whereby, as before mentioned, the cylinder will lose less heat.

In Figs. 48 and 49 the intercepting oscillating lever *q* consists of a bent strip of metal, pivoted upon the

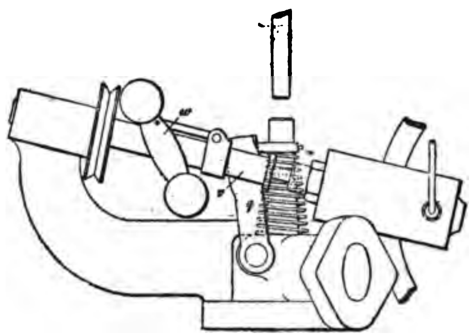

FIG. 48.—Modified Form of Roots' Governor for Petroleum or Explosive Engines (Front View).

exhaust valve box, and which is directly controlled by the sleeve *v* of the governor *w* for the purpose above described.

In a subsequent arrangement of the motor, the piston, although preferably in one casting, is made of two diameters, the smaller one being connected to the connecting rod and reciprocating in the guide portion or smaller diameter of the cylinder, which is unjacketed, and is bolted on to the front of the larger portion, forming its front cover. The air is drawn into the annular

space on the cylinder front surrounding the smaller diameter of piston, through a port in the cylinder wall, a portion of this air is displaced or ejected through the same port on the return stroke, the rest is compressed and a portion of this is forced through a port to the other side of the cylinder through the admission valve, without any fuel, either gas or oil vapour, being mixed with it, then the larger part of the air so compressed is mixed with gas or oil vapour, and flows through the same valve or port to the combustion side of the piston and working end of the

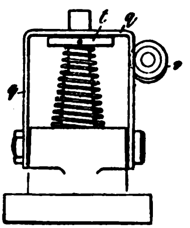

FIG. 49.—Modified Form of Roots' Governor for Petroleum or Explosive Engines (End View).

cylinder, where it is ignited by a hot tube after compression. The piston performs the working stroke, and the exhaust valve is opened just before the working stroke ends, when the pressure has fallen to nearly that of the atmosphere, the exhaust products are then displaced during the return or inward stroke of the piston for about half the stroke, the exhaust valve closes, and the remaining contents of the cylinder and combustion chamber are compressed and fired.

This arrangement admits of an impulse being obtained at every revolution, and also a much greater expansion, without, the inventor says, a wasteful back

pressure on the piston existing through so large a portion of the stroke, whilst at the same time the likelihood of the charge firing on entering is reduced to a minimum, as air only enters first.

The feed of oil is effected and measured by a spindle rotated or partially rotated by the engine. Upon the spindle a deep thread is cut for a portion of its length. This spindle rotates in a casting drilled to fit it, containing an oil channel in connection with the oil tank, also an air channel, and the screw during rotation conveys oil from the oil channel to the air channel, where it is swept off by the heated air. The size of the screw groove and the number of rotations determine the feed of oil. The governor is connected to the spindle, so that at excess speeds the screw-threaded portion will be pulled out of the oil, or cease to rotate, leaving in the oil a plain or uncut part of the spindle, and the feed will consequently be arrested. This arrangement may be modified by making the spindle slightly conical, and cutting pockets in it, one for each cylinder, if more than one, the oil space or channel is then placed at an opposite point to the air channel, so that on the spindle rotating, each pocket will be brought opposite the air channel, which will be so placed that the heated air will sweep directly into the oil pocket, and clear out its contents.

For petroleum, the burner used consists of a small coil of pipe enclosed in a casing, which may be lined with non-conductive material. One end of the pipe that is connected to the burner coil is also connected to the oil feeder and to a blower or bellows of any known type, and the other end of the coil is bent round so as to direct the issuing stream of oil and air

straight through the coil in which the oil is mixed with the air, and both are heated together on their passage through the coil burner, and produce a blue or atmospheric flame.

Figs. 50 to 54 show an improved vaporiser, oil feeder, and burner.

Referring to Fig. 50, Z is the air and oil heating casing, and Y the oil feeder. The spindle of the air inlet valve is placed horizontally, and the air pipe E^1 is divided into two parts, the one for conveying air to

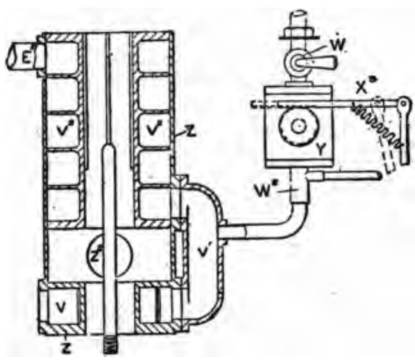

FIG. 50.—Roots' Vaporiser and Oil Feeder for Petroleum or Explosive Engines.

the air and oil heating casing Z, and the other for conveying the said air directly to the admission valve box.

In Fig. 51, W is the oil cock, W^1 is the oil space, X the screw thread which conveys oil from the oil space W^1 to the air space Y^1, whence it is conveyed by the pipe W^2 to the air channel V^1 (Fig. 50), which connects the vaporiser channel V with the air heating channels V^2. The oil feed casing Y may be cast in one with the air channel V^1, as shown in the modified

arrangement illustrated in Figs. 52 and 53. Also if a very heavy oil be used, the pipe W^2 may feed its oil into the top of the channel V^2 in order to pass the oil and air together through a greater length of the said channel.

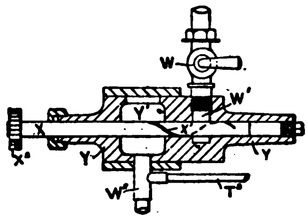

FIG. 51.—Roots' Oil Feeder for Petroleum or Explosive Engines (Longitudinal Section).

The spindle X, with its screw thread or spiral groove X^1, is rotated by means of the toothed wheel X^2 on the projecting end thereof, which gears into the toothed

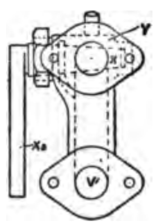

FIG. 52.
Modified Form of Roots' Oil Feeder (Elevation).

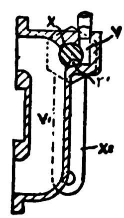

FIG. 53.
Modified Form of Roots' Oil Feeder (Vertical Section).

rack X^3 (Fig. 50), which is operated from the admission valve G by means of a lever connected to its spindle.

In Figs. 52 and 53 the spindle X is made shorter, and tapered like a plug, and, moreover, has cut in it a

pocket X^1, which, on the spindle being given a to-and-fro movement or partial rotation by means of the arm X^2, becomes filled with oil and is presented to the heated moving air which sweeps out the pocket.

The burner, Fig. 54, is formed of a coil of piping U, surrounded by a tubular casing T, which may be lined with asbestos. To start the engine the burner is heated and supplied with oil by means of an ordinary syphon wick from the oil tank, through the two-way cock shown, and with air by means of an ordinary hand pump or fan. When the ignition tube and vaporiser are sufficiently heated by the flame from the burner playing through the hole Z^2 in the casing Z

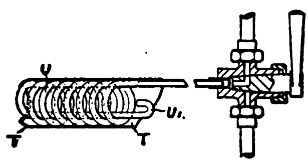

FIG. 54.—Roots' Improved Burner.

(Fig. 50), the two-way cock is turned, and the burner is supplied with air and oil by means of the pipe T^2 on the oil feeder Y (Fig. 51), which is connected to the said two-way cock. The air and oil are heated and mixed by passing through the coil U so that they form a complete gas, the said mixture issuing from the end of the bend U^1, and being injected into and mixed with further air in the tube casing.

Figs. 55, 56, and 57 show an improved valve opening mechanism by which the engine is made reversible.

To permit of the engine being started and working equally readily in either direction, a portion of one of the toothed wheels is cut away on its inner or bearing

surface, so that in whichever direction the fly-wheel may be turned to start the engine, the toothed wheel will slip round on the shaft or pin until stopped by the key. The stop position at each end of the segmental slot is the valve opening position. For the

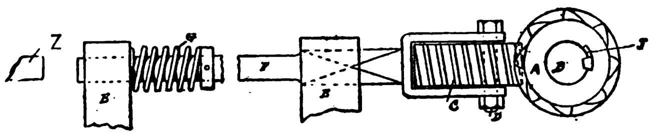

FIG. 55.—Roots' Reversible Valve-opening Mechanism for Petroleum or Explosive Engines.

same purpose, a slot might be cut and a set screw fitted; or the cut-out piece or slot might be made in intermediate mechanism between the valve and the gearing, so as to operate it once in two revolutions.

A is the worm of the screw gear fitted on the shaft

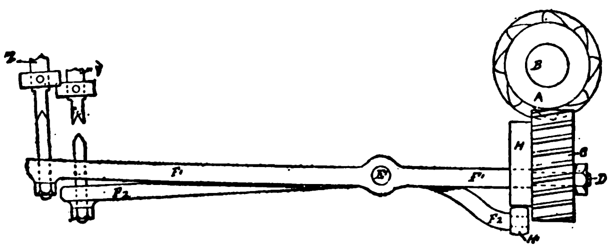

FIG. 56.—Slightly Modified Form of Roots' Reversible Valve-opening Mechanism (Side View).

B, and gearing into the pinion C, which is fitted on the pin D, and rotates at half the speed of the worm A. In Fig. 55, E, E, are the bearings of the reciprocating side shaft F. G is a spring which keeps the worm and worm-wheel in gear. Z is a portion of the valve

spindle which is operated to open the valve by the reciprocation of the rod F. In Figs. 56 and 57 the pin D forms part of the lever F^1, the eccentricity of which in the pinion C when the wheel rotates oscillates the lever F^1 on the fulcrum E^1 and opens the exhaust valve through the spindle Z. The cam H is screwed or otherwise fixed on the pinion C, and in rotating with it operates the lever F^2 by means of the antifriction roller H^1 and opens the admission valve through the spindle Y.

In Fig. 55 a portion of the inner wearing surface of the worm A is cut away at J to admit of its making the necessary free movement on the shaft to open the

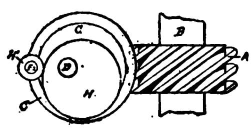

FIG. 57.—Slightly Modified Form of Roots' Reversible Valve-opening Mechanism (End View).

valve at the right time every other revolution, when the engine is going in the opposite direction. When the key is in position at one end of this cut-away portion J, the parts are so adjusted that the valve will be opened in going one way, and the other end of the said space is the position for the opposite direction of rotation.

Figs. 58 and 59 is an improved ignition device and arrangement of spray nozzle for that class of oil engines usually known as those of the internal vaporiser type, that is to say, wherein the oil is sprayed into the working or combustion cylinder without external vaporisation.

It has been demonstrated by experiment that when oil is sprayed into a working cylinder the essential thing is ignition, as the oil has not time to be, and is not, vaporised, but is fired as oil spray, and that once the ignition is commenced, the flame passes almost as rapidly through the particles of oil as oil spray, as through a completely vaporised and mixed charge of oil. The inventor's object, therefore, is to so construct the device as to get the ignition tube in line with the issuing spray, and so to ensure the immediate ignition thereof. The spray nozzle, fed by a pump driven by the side or valve shaft of the engine in the usual manner, is fixed on the side of the cylinder cover. A casting is bolted on the inside of the cover and over a port or hole in the cover wall. The casting is a flanged cylinder closed at the inner end by a dome-shaped end. It is of elongated U or basin section, and has screwed across it, at right angles with its axis, the ignition tube, so that the inner surface of the U casting and the outer surface of the tube are open to the outer air. The ignition tube is placed in direct line with the spray nozzle so that the issuing spray enters the tube, and this part catching fire, the whole spray is ignited and explodes. The flame of a lamp is directed upon the tube to heat it.

Although other tubes may be used, a porcelain one is found preferable, and this, together with the egg-ended cylindrical or U casting, is afterwards kept hot by the combustion of the successive charges, and the tube being thin, is kept at a sufficient temperature to continue the ignition of the said charges.

The ignition tube shown in Fig. 58 is fixed at one end only in the cylindrical casting, and closed at the

other. That shown in Fig. 59 passes through both walls of the said casting, and is open to the combustion space at both ends.

The spraying oil nozzle used is of the ordinary construction, and is so arranged that it projects in a line with the ignition tube and that the oil spray enters it. A rib or flange is formed on the cylinder for the two-

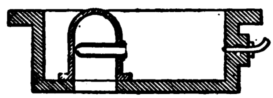

FIG. 58.—Roots' Improved Ignition Device.

fold purpose of strengthening it, the whole being preferably made of thin metal or of porcelain, and also to offer an increased surface to receive and store heat from the combustion after starting. This flange may be perforated.

When the tube is red hot, and the engine is running,

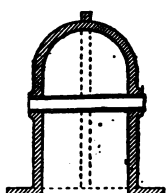

FIG. 59.—Modified Form of Roots' Improved Ignition Device.

the lamp flame used to heat it can be removed or extinguished, in which case the port or opening should be closed by a plug to retain the heat of the tube and the cylinder.

It is stated that in the case of small engines the cylindrical or U tube itself can be used for ignition, especially if made of porcelain, and the cover be so

constructed that the U tube projects inwards over the port into the combustion space, and that the spray nozzle be fixed in such a position as to throw the spray upon it.

In another arrangement of motor shown in Figs. 60 to 62, the four-stroke or Otto-cycle of operations are carried out on both sides of the same piston, on the one side by the usual process of charging with explosive mixture, compressing, igniting and expanding, and exhausting, and on the other side by charging with air

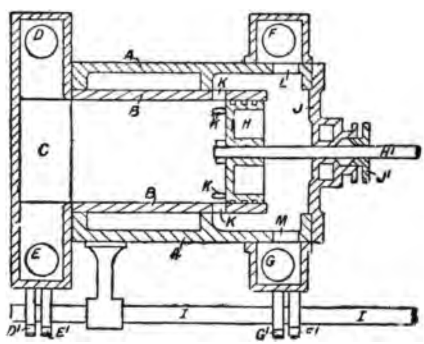

FIG. 60.—Modified Form of Roots' Explosive Engine (Horizontal Section).

only, compressing the said air, heating it up by exhaust gases admitted at higher pressure and temperature from the other side of the piston, and expanding the hot mixed gases so produced to give a power stroke simultaneously with the exhausting stroke on the combustion side of the piston.

A is the cylinder enclosing the water jacket, B the liner or working barrel, C the cover, D the combustion and exhaust valve, E the admission valve for the admix-

ture of fuel and air, E^2 (Fig. 61) the port through which the mixture enters to the valve E, F the second expansion exhaust valve, G the admission valve for air to the second expansion end of cylinder, D^1 the lever for opening the exhaust valve D, E^1 the lever for opening the admission valve E, E^3 (Fig. 61) the eccentric for operating the lever for opening the valve E, D^2 the eccentric for operating the lever D^1. The other levers and eccentrics are omitted from Fig. 61 for the sake of clearness. G^1 and F^1 (Fig. 60) are the levers for opening the valves G and F respectively. It must be understood that the fork ended levers and eccentrics are only an alter-

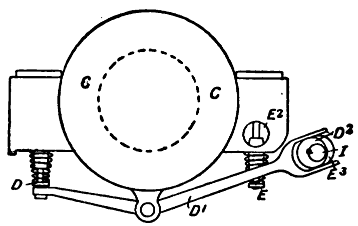

FIG. 61.—Modified Form of Roots' Explosive Engine (End View).

native method of opening the valves, as the usual arrangement of cams and levers may be employed.

H is the piston, H^1 the piston rod, I the usual rotating side shaft, J the expansion end cover, J^1 the piston rod stuffing box, K, K, the communicating piston valves or ports opened by the piston at the end of its stroke, L the port leading from the second expansion end J of cylinder to the exhaust valve F, M the port for admitting air to the same end through the valve G.

Fig. 62 shows an improvement in the oil feed. N is the oil space fed from the oil tank, O is the air space through which the heated air passes on its way to the

cylinder, P the oil feed spindle, Q the oil feeding groove to supply oil to the air in the channel O, R the oil feeding groove to supply oil to the burner, S the air supply pipe from the pump, T the end or socket into which the pipe leading to the burner is screwed.

The oil vapour is supplied in any known or usual manner through the port E^2. Ignition is effected in the usual manner by a hot tube in the combustion end C. The exhausts D and F are connected in a manner not shown in the drawing to one exhaust pipe. The four strokes completing the cycle in the combustion end C, viz., suction, compression, explosion, and exhaust, are effected in the usual manner, but when the

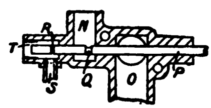

FIG. 62.—Roots' Improved Oil Feeding Device for Explosive Engines (Vertical Section).

piston uncovers the ports or valves K, K, the hot gases rush through them into the air that has been compressed on the other side of the piston. This air drawn through the valve G is compressed to about 20 lbs. by the return stroke of the piston, when the ports K, K, are uncovered by the piston; but the pressure may vary in different engines. The pressure of 20 lbs. or thereabout is raised to 35 or 40 lbs. by the combined effects of the increase in the quantity of the gases on this side of the piston, and by the rise in the temperature of the whole quantity of gases on the expansion side of the piston. Simultaneously with the closing of the port valves K, by the return of the piston H, the exhaust valve D is opened by its eccentric or

cam and lever, and the combustion end C of the cylinder is exhausted in the usual way. A working stroke takes place, on the expansion or non-combustion end J, and just at the end of this stroke, the exhaust valve F is opened, and the mixed products and air are exhausted by the return of the piston.

It will be observed that the air is heated at the com-

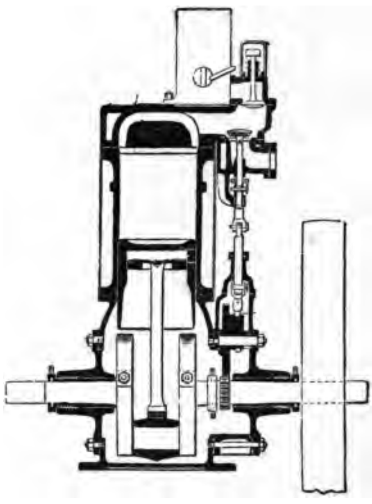

FIG. 63.—Roots' Single Cylinder Carriage Oil Motor (Latest Type).

mencement of each stroke, and that a similar series of operations take place at both ends of the cylinder, but in the end C ignition and combustion take place, while in the end J the air is heated by the waste heat of the combustion in C. A certain quantity of mixed air and gases also flows into the combustion end C, through the valves K from the non-combustion end J, at the end

of the suction stroke on the combustion side of the piston, thereby increasing the compression and the mean pressure on that side.

Fig. 63 illustrates in vertical central section one of the most modern types of Roots' petroleum engines. The improvements, which are chiefly in minor details of construction, will be very readily understood from the drawing. It will be seen that the oil feed spindle is of the usual kind used in Roots' engines, as likewise the casing with the air heater and vaporiser, and nickel silver ignition tube. The valve motion is fitted with a rocking weight governor, and a handy arrangement of tapers on shaft and brasses enables the slack to be taken up when necessary. The motor is reversible, being capable of being started in the opposite direction.

It is claimed by the inventor that the smell common to engines of this type is very considerably reduced in this instance, owing to the form of the piston employed, which catches and condenses the escaping vapour. The consumption of oil is said to be about 1 pint per brake horse-power per hour, and the cost of running is therefore about one halfpenny per horse-power per hour. Oil of a specific gravity of .8 and upwards may be used as fuel.

Roots & Venables' Oil Engine Road Carriage.

A double cylinder engine of this type is employed as the source of energy upon the Roots & Venables' petroleum road carriage, which is known as the "petrocar."

This carriage is adapted to accommodate two passengers, and has a steel framework carrying the oil engine, cooling water tank, exhaust box, and cooling coil, and is mounted upon three wheels fitted with solid indiarubber tyres. The front or steering wheel is spring mounted in a fork, and is operated by a lever with a handle bar, in a somewhat like manner to that of a Bath chair. An ordinary cycle plunger brake is fitted to this front wheel, and a powerful band or strap brake is also fitted to a drum keyed on the axle of the rear or driving wheels. Four sliding blocks, having ball bearings and fitted with springs, are arranged in guides of an inverted **U** shape in connection with the main axle. A balance gear is fitted to a sleeve upon the said main axle, and a two speed gear, composed of toothed or spur wheels and a clutch, is likewise fitted to gear down or reduce the speed of the motor, to enable the rate of speed to be changed for hill climbing, &c. The transmission gear consists of chain or sprocket wheels and pitch chains, the smaller sprocket wheel being fitted loosely upon the crank shaft, and its connection with the latter being operated through a friction disc keyed upon the former. The cooling water tank is bolted to the frame beneath the feet of the passengers, and the exhaust box is located at the rear end of the said frame.

The engine employed on this vehicle is one of 2½-brake horse-power, and it is said that Russian and American petroleum oils can be used of any specific gravities between .8 and .835, and with a flash-point by the Government test up to 130° F. The total weight of the vehicle and motor, &c., is about 9 cwt.

The Britannia Company's Oil Engine for Road Carriages (Gibbon's Patent).

A type of petroleum motor applicable for the propulsion of motor cars is that known as the "Facile," which is made by the Britannia Company under Gibbon's patent, and which would seem to possess several features rendering it specially qualified for use in the propulsion of motor cars. Amongst the

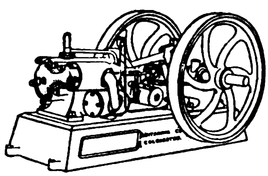

FIG. 64.—Britannia Company's (Gibbon's Patent) Horizontal Petroleum Carriage Motor (Elevation).

FIG. 65.—Britannia Company's (Gibbon's Patent) Vertical Petroleum Carriage Motor (Elevation).

advantages claimed for this engine are the following: —Extreme simplicity of construction, one valve only being employed; an impulse is effected at every revolution; no vaporiser is required; after a short preliminary heating the ignition is automatic; the cylinder does not become overheated, owing to the provision of a separate explosion chamber; and the waste heat is utilised to heat the ingoing charge, thus

ensuring economy, and reducing the quantity of water required to maintain the engine cool.

This engine is made in both horizontal and vertical patterns, the external appearance of which are clearly shown in the illustrations (Figs. 64 and 65), the former of which represents the horizontal and the latter the vertical type of engine. The principle upon which these engines are built is practically similar, and they differ only in the necessary details of construction to enable the parts to operate in the different positions.

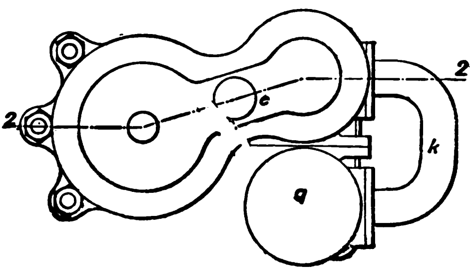

FIG. 66.—Britannia Company's (Gibbon's Patent) Petroleum Carriage Motor (Plan).

The internal and working arrangement of both will therefore be readily understood from the detail views of the engine shown in Figs. 66, 67, 68, 69, and 70, and the following description relating thereto which appeared some time back in the *Engineer* :* —

"*a* is the framing of the engine, and *b* is the power cylinder, which is provided with a water-jacket *c* in the usual manner. *d* is the combustion chamber, which is connected to the cylinder *b* by a short neck

* The *Engineer*, 5th July 1895, vol. lxxiii., p. 539.

or passage *e*, and which is preferably of much smaller diameter than the cylinder, and placed parallel thereto, as shown in Fig. 67. *f* is the jacket surrounding the combustion chamber, *g* is the valve-box, and *h* is the valve working therein, and serving both as an air

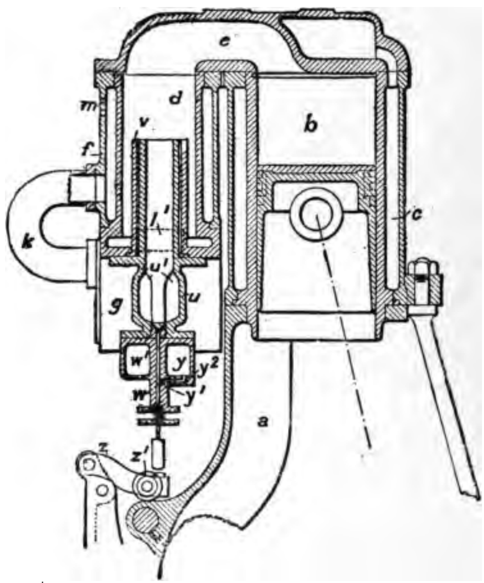

FIG. 67.—Britannia Company's (Gibbon's Patent) Petroleum Carriage Motor (Section on line 2–2, Fig. 66).

inlet valve and an exhaust valve, the space *i* above the valve communicating by the passage i^1, seen at the bottom of the vaporiser u^1 in Fig. 67, directly with the interior of the combustion chamber *d*, whilst the space beneath the valve is in communication through the ports *j*, *j*, and the pipe *k* with the jacket

f, and by the ports *l*, *l* with the atmosphere according to the position of the valve *h*. *m*, *m* are holes formed in the jacket *f* for admitting air thereinto for the formation of the explosive charges. The valve *h*—which

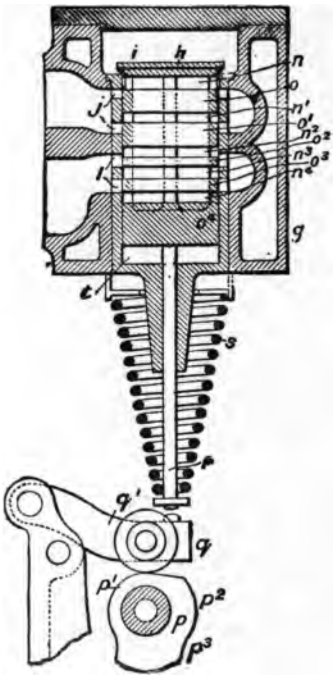

FIG. 68.—Britannia Company's (Gibbon's Patent) Petroleum Carriage Motor (Enlarged Section through Valve).

as shown in Fig. 68, is a mitre valve—is provided on its under side with a hollow cylindical extension which fits within the valve-box *g*, and is provided with a series of circumferential apertures or openings n, n^1, n^2, n^3, n^4, communicating with the ports *j*, *j*, *l*, *l*.

"During the compression and combustion stroke of the piston, the valve *h* is in the position shown in Fig. 68. When the exhaust stroke of the piston commences, the cam p^2 lifts the valve *h* from its seat, and places the apertures n^3, n^4 opposite to the ports

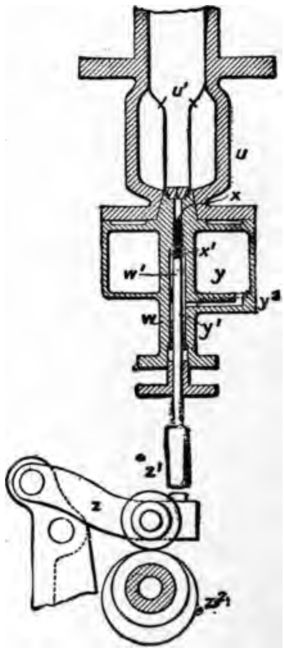

Fig. 69.—Britannia Company's (Gibbon's Patent) Petroleum Carriage Motor (Enlarged Section through Oil-Feeding Device).

l, *l*, so that the gases from the cylinder *b* can pass under the valve *h* into its cylindical extension, and thence escape through the apertures n^3, n^4 and the ports *l*, *l* to the atmosphere. During the time that the ports *l*, *l* are open, the air inlet ports *j*, *j* are closed

by the rings *o*, o^1. On the completion of the exhaust stroke, the lift p^3 of the cam raises the valve still further, the ports *l*, *l* are closed, the apertures n^1, n^2 brought opposite the ports *j*, *j*, and on the outgoing stroke of the piston air is drawn through the holes *m*, *m* into the jacket *f*, and thence through the pipe *k* and the ports *j*, *j* into the valve-box, whence it passes into the cylinder *b* through the aperture i^1.

"In Figs. 67 and 69, *u* is the vaporising chamber and igniter, which is arranged partly within the combustion chamber *d*, and partly outside it, the part outside being, as shown in the drawings, provided with internal ribs u^1, u^1, and being heated for starting the engine by the flame of a lamp. After the engine has been running for a short time, the part of the chamber *u* within the combustion chamber *d* will, it is said, be sufficiently heated to serve as the igniter.

"A shield *v* is placed around the portion of the vaporising chamber and igniter *u* within the combustion chamber *d*, but with an intervening annular space, for the purpose of preventing the air entering the combustion chamber from impinging against the walls of the chamber *u* and cooling it. The shield *v* is placed at a slight distance from the chamber *u* in order to afford a space into which the gases can penetrate.

"In Figs. 69 and 70, *w*, w^1 are the barrel and plunger of the oil pump for injecting the oil into the vaporising chamber *u*. The pump is constructed as shown in Fig. 69. In the end of the plunger is formed, for a short distance, a passage *x*, which terminates in a cross passage x^1, as shown most clearly in Fig. 70. Around the barrel *w* of the pump is formed a chamber *y*, and

around a portion of the plunger of the pump is formed a space y^1, which communicates with the chamber y through a passage y^2, the space being kept constantly filled with oil under a slight head or pressure. When the plunger is full out, the cross passage x^1 is in the space y^1, so that the oil can flow from the latter into the passage x, and fill the space above the plunger; immediately the upward movement of the plunger commences, the passage x^1 is moved into the part of the pump barrel which the plunger fits, so that the return of oil through the passage x^1 is prevented—the result being that the oil in front of the plunger is injected

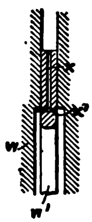

FIG. 70.—Britannia Company's (Gibbon's Patent) Petroleum Carriage Motor (further Enlarged Portion of Fig. 69).

into the vaporiser u. The engine is well mounted on a strong wrought-iron frame, and is fitted with a water-cooler."

It will be seen that the motor has but one valve, which is similar to a large safety-valve having a series of pistons in place of wings, and which valve acts both as a main air valve and an exhaust valve, and is kept cool by the air during its passage into the cylinder. The motor is of what is known as the internal vaporiser type—that is to say, that class of engine wherein the said vaporiser likewise forms the ignition tube, and the said igniter is contained in a casing attached to an

extension of the cylinder cover wherein is located a way or passage communicating with the said casing, the combustion space being thus placed at the side instead of at the rear of the cylinder. The supply of air passes through the above-mentioned compound valve and round this casing to the cylinder, and the fuel or oil is injected into the bulbous end of the vaporiser by a rod working in an oil box, and having a longer or shorter stroke imparted to it, and therefore injecting more or less oil in accordance with the controlling action of the governor. The governor acts on a cam, so as to allow to a trip finger a longer or shorter time to remain in contact with a rod which it operates or pushes. The engine, it will be remarked from the above, combines the features of some other engines already known.

The Britannia Company's Oil Motor Road Carriages.

The above-described combustion engine forms, as may be supposed, the main feature of the Britannia Company's motor carriages, of which they make several patterns, viz., a three-wheeled carriage fitted with a 1 horse-power engine adapted for one passenger, or two on an emergency, and estimated to be capable of travelling at a speed of from 2 to 10 miles an hour on level roads ; a three-wheeled carriage fitted with a 2 horse-power engine adapted to carry two passengers seated side by side, and calculated to develop a speed of from 2 to 14 miles per hour on level roads ; and a four-wheeled carriage of the *vis-a-vis* style, fitted with a 4 horse-power engine, and having an estimated speed of from 2 to 15 miles per hour on the level.

The "Facile" carriage motor is, however, also applied to omnibuses, tram-cars, goods delivery vans tricycles, and many other classes of vehicles.

Noticeable features in the driving or running mechanism or gear of the Britannia motor cars are the following:—Their patent improved speed variation gear, by means of which the carriage can be made to travel either fast or slow, whilst the engine, of course, runs at its ordinary or normal speed; the improved self-acting governor, by which the speed of the engine is automatically adjusted on ascending or descending hills, thus saving one handle; and the dispensation of a number of more or less complicated parts common to many other engines, which admits of the mechanism being controlled by means of only two handles and one foot lever. It is also claimed for the motor that cleansing of the parts can be very easily performed, the double purpose or compound valve being capable of being removed, cleaned, and replaced in position in about ten minutes. The carriage, it is stated, can be started when all is in proper order in about six minutes, and ordinary petroleum lamp oil of a specific gravity of .8 upwards may be employed, which is obtainable almost everywhere. The cost of running is placed by the makers at about a halfpenny per brake horse-power per hour, the consumption of oil being at the rate of about one pint per hour per brake horse-power.

Other Types of Oil Engines and Road Carriages.

Amongst the numerous other patterns of internal combustion engines and motor cars to which, as already

mentioned, space will only admit of a brief allusion being made, may be mentioned the following :—The Pygmée, the Seck, the Lepape, the Tenting, the Loyal, the Gladiator, the Dawson, the Maxim, and the Riotte.

Pygmee Oil Engine for Road Carriages.

The first of those above mentioned, or the Pygmée motor, is one which, in point of efficiency, equals if not surpasses the Daimler motor. The arrangement of the various parts is such as to ensure the compactness of the engine without in any way curtailing their dimensions, and the motor can also be managed with remarkable facility. These motors are built in both vertical and horizontal types, the latter, however, being usually employed for motor cars.

The engine is balanced, having two cylinders with pistons working cranks placed at 180°, thereby to a very great extent obviating the intense vibration otherwise set up by the alternating motion of the parts. The admission valves are opened in the usual manner by the suction action of the pistons, and the exhaust valves are arranged in boxes and are operated by cams upon an intermediate shaft.

The speed regulating device is ingenious, and deserves some notice. It consists essentially of a rod carried by the fly-wheel and connected with a centrifugal regulator. The revolution of the fly-wheel will tend to force this rod from right to left against a spring, the tension of which can be adjusted by means of a thumb-screw. Upon the engine attaining what is considered to be an excessive speed, the pull of this

spring will be overcome, and the rod will be moved so as to operate the exhaust valves, thereby preventing the burnt gases from escaping, and consequently the piston will draw a fresh charge into the cylinder on the next stroke, and in this manner bring back the engine to the normal speed as regulated by the spring. Should, however, the stoppage of the action of one cylinder be insufficient to reduce the speed, the said rod will travel still further to the left, and in like manner stifle the exhaust of the second cylinder.

The carburator consists of a spiral tube or coil surrounding the ignition burners, and either spirit or petroleum can be used; in the latter case, however, the above-mentioned spiral tube is arranged within the burner instead of outside as before. A special arrangement of the air and vapour admission ports causes the gas to whirl and become thoroughly mixed before entering the cylinder, and thereby minimises the chances of failure to explode.

The compression used in this engine is high, amounting to 57 lbs., and the consumption of spirit or petroleum is thereby rendered very low, not exceeding, it is stated, .968 lb. per horse-power of motor per hour.

Seck's ("Gnome") Oil Engine for Road Carriages.

Seck's oil engine, which is known as the "Gnome," and is built by L. Séguin, is also a very simple and efficient type, possessing the advantage of being capable of being satisfactorily handled by persons with but little experience; as at present constructed, however, it is much too heavy for motor cars, and

is more suitable for use as a portable oil engine for agricultural purposes or for light locomotives.

It is a single-cylinder engine, cooled in the ordinary manner by a water jacket, and the charge is admitted during the first forward stroke, the petroleum passing through a vaporiser heated by a burner, and a suitable amount of air being allowed to gain admission through a small aperture. The vapour on entering the cylinder is met at right angles by, and thoroughly mixed with, a sufficient supply of air to admit of combustion taking place.

The petroleum is fed from a main reservoir to the vaporiser by a small pump, an overflow maintaining a constant level in the former. The method employed for operating the exhaust valve comprises a horizontal slide valve to which reciprocating motion is imparted by an eccentric and endless screw. The regulation of the speed of the motor is effected by preventing the exhaust valve, through suitable mechanism, from falling upon its seat when the speed is increased above the normal, thereby producing, though in a different manner, a like result to that effected by the usual plan of preventing the exhaust valve from opening on the occurrence of any abnormal or excess speed.

Lepape's Oil Engine for Road Carriages.

The Lepape is a three-cylinder engine, the charge being admitted and expelled through valves in the usual manner, and electric ignition of the charge being employed. The cylinders are placed at an angle of 120° to one another, with a view presumably of equalising the strains and reducing vibration to the lowest

possible point. There is nothing further, however, in this motor specially worth describing.

Tenting Oil Engine for Motor Carriages.

The Tenting oil motor is a double-cylinder, water-jacketed, Otto-cycle engine running at the comparatively low speed of 250 revolutions per minute. The valves controlling the admission and exhaust are arranged horizontally. The engine is light and well made, but no special novel features apparently are included in its design.

Loyal's Oil Engine for Road Carriages.

The Loyal motor is of the single-cycle type, and has an oscillating unjacketed cylinder mounted on trunnions, through one of which the gas or vapour is admitted to the explosion chamber.

The special feature of this engine is the ignition device, which consists simply of a nickel tube in which the gas mixture is compressed to a sufficient extent to produce the necessary heat for firing, the ignition tube requiring, however, a short preliminary heating when starting.

A special form of carburator has also been designed by Mr Loyal. This apparatus comprises a reservoir divided into two compartments by a conical-shaped partition, in the uppermost of which is located the gasoline. The feed of gasoline into the lower or carburating chamber is automatically regulated by a spindle extending vertically into and through the lower compartment, and having a conical valve which, when the engine is at rest, is held by the action of a spiral spring against a seating in an orifice, in the

apex of the conical partition, and thus prevents the passage of any gasoline therethrough. Below the said conical valve is a small fan or screw which, when the spindle is revolved by the suction action caused by the motor itself, and the oil is permitted to drop upon the said screw from the reservoir, is also revolved, and this action in combination with that of the air acts to vaporise the petroleum and carburate the said air, which latter is then removed to the explosion chamber through a pipe passing upwards through the upper or petroleum compartment of the carburator.

Darracq's (Gladiator) Oil Engine for Road Carriages.

The Gladiator oil motor, which is from the designs of Mr Darracq, is of the Otto-cycle type, and is provided with a water-cooled jacket at the explosion end of the cylinder only. The ignition tube is heated to a white heat by a Longuemarre burner * fed from a special oil reservoir, a slight pressure in which latter must be maintained by means of a small force-pump at starting.

The valves are governed by springs, that for admitting the charge, which is sucked in automatically, closing the valve after each inspiration, and that controlling the exhaust being held by a powerful spring, and raised every alternate revolution by means of a lever and operating cam carried upon an intermediate shaft.

The exhaust is passed into an exhaust box or silencer

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* See pages 52, 88 for further description and illustration of this burner.

which is divided into two compartments, the first of which is filled with fine steel filings, and the second, or the one on the outlet side, with coarser ones. By this means all noise is said to be completely deadened or silenced.

Dawson's Oil Engine for Road Carriages.

The Dawson motor has a single water-jacketed, valveless cylinder, wherein the explosions are effected by means of an incandescent tube. The piston is of the barrel pattern, and means—comprising a worm wheel engaging with a worm on the crank—are provided for rotating it upon its axis in the cylinder, during its to-and-fro working therein; the connection of the rod upon its axis to the piston is made by a ball and socket joint to admit of this action.

Two holes or ways placed in the same horizontal plane are provided in the piston, and two similar ways are formed in the cylinder for the admission of the explosive mixture thereto, and for the exhaust of the burnt gases therefrom. The admission of the charge is effected during a portion of the outward stroke of the piston, and on the return or inward stroke thereof the charge is compressed, and the ignition tube being uncovered, explosion takes place; the exhaust passage being next uncovered and the burnt gases removed. These various actions are effected by the combined longitudinal and rotary movements of the piston.

Maxim's Oil Engine Road Carriage.

The Maxim oil engine is a three-cylinder one of the Otto-cycle type, one-sixth of a revolution being only

left without impulse. The cylinders are constructed of cold-drawn seamless steel tubing, $\frac{1}{16}$ inch in thickness, and the ignition is effected by an electric spark, the current being supplied by a battery having nine chloride cells. This motor, which is said to develop $1\frac{1}{2}$ horse-power, only weighs about 32 lbs.

An engine of this type was fitted to a tricycle, which was one of those shown, but not run, at Chicago, in connection with the competition trials of motor cars held there.

Riotte's Oil Engine Road Carriage.

The Riotte engine was fitted to a bicycle which was exhibited at Chicago under like conditions to the one previously mentioned.

The motor has an oscillating cylinder, and its piston rod is connected to a crank disc on the axle of the rear wheel, the explosions being effected by an electric ignition device. There are no marked features in its construction calling for any special mention, but it is characterised as a whole by extreme lightness, the weight of the motor, oil supply for a 75 miles' run, and electric battery for the ignition device, being only 9 lbs.

It is stated to be capable of attaining a speed of 20 miles an hour on a good level road, and to be able to surmount up-grades of 4 per cent. at a fair rate of speed.

Triouleyre's Oil Engine Road Carriage.

M. Triouleyre's motor carriage, which is built by the Compagnie Générale des Automobiles (Paris), is one

which is said to have performed some first-class running. Two vehicles of this type were entered for the Paris-Marseilles race.

This car is driven by a benzoline motor, which drives a second motion shaft by means of leather belt gearing, and from which second motion shaft power is transmitted to the driving wheels by chain or sprocket wheels and pitch chains. The most noticeable feature, however, in the arrangement is the provision of a set of tubes and an air-blast for cooling the water from the cylinder jacket.

CHAPTER V.

ELECTRIC MOTOR CARRIAGES.

AT the present time there does not seem to be much chance that electricity will be able to compete with either steam or internal combustion engines in economy of working, and that even in the United States where the wider use of electricity has cheapened its production, and it is therefore more favourably placed with respect to these motive powers.

An electric motor varies in efficiency in direct accordance with its weight. This gives rise to a very grave objection when applied for purposes of propulsion, where increase of the dead weight becomes obviously a matter of very considerable importance. The efficiency of the electric motors at present in use is at most about 80 per cent. when developing average power, and this percentage is greatly reduced every time they are called upon to give out additional power upon any emergency.

The great drawback, however, to the use of electric motors for haulage purposes lies in the question of the difficulty of obtaining the requisite supply of electric current. But two methods of doing this are available, viz., by generating the said current upon the vehicle itself, which can be done either by means

of primary batteries, or by a dynamo electric machine worked by an oil, steam, or other engine; and by laying by in storage batteries or accumulators a sufficient supply of electricity to perform the journey or a certain portion of it. The use of primary batteries is impracticable by reason of the cost of producing a powerful current by that means, and the employment of a dynamo and oil or other motor would be also both expensive and heavy, consequently the latter or storage batteries, as presenting obviously the most feasible method in practice, is the plan that is usually adopted; but even this method of supplying the current gives rise to several very serious objections, foremost amongst which is that of weight.

As is well known, the accumulators or storage batteries in use at the present day do not differ in principle from those primarily devised by Planté, and lead plates are still employed as electrodes, and highly diluted sulphuric acid as the electrolyte. The result of this is that the weight of the accumulators is excessive, being at the rate of about 1¾ cwt. per horse-power per hour. From this it will be seen that the weight of an accumulator that would keep the vehicle running for say about a couple of hours on average roads at a speed of about 12 miles per hour, without being recharged, would exceed the combined weight of both the carriage and passengers.

Besides this, however, there is the loss experienced between the power expended by the dynamo in charging the accumulators and the return of the latter, the efficiency of which rarely reaches above 75 per cent., the loss experienced in the working of the

electric motor, the efficiency of which is seldom more than 80 per cent., and the loss in the dynamo, the efficiency of which may be taken at most to be about 90 per cent. There is therefore a total loss of the work done by the steam, gas, or other motor in driving the dynamo of over 50 per cent. This enormous loss easily accounts for the reason why electric traction even upon comparatively level tram lines is dearer than that of animal traction, where accumulators are employed for storing the necessary supply of electricity. Overhead wires delivering the current to the motor on the car through a collecting trolly is a far more economical system, but is of course inapplicable to motor cars for common roads.

Still further objections to accumulator electric motor cars are that the accumulators require recharging or replacing by ones already charged, after a comparatively short time, thus rendering them in many cases absolutely useless, and being at all times most inconvenient and troublesome; and moreover there is the loss due to the depreciation of the accumulators themselves.

This recharging can, of course, be easily effected in large towns and cities, but in the country, except in the case of large houses possessing their own electric lighting plants which could be utilised, a special and expensive plant would have to be provided for charging the batteries. Where an electric light plant, worked by water power, happened to be available for charging purposes, there would be a very considerable saving in power, but these cases are rare.

It is quite true that the electric car possesses certain advantages over oil, steam, or indeed any other engines or motors for the purpose under consideration. For

example, it can be controlled with greater facility; it is practically safe and free from any chance of dangerous explosions and other accidents; and last, but by no means least, it does not discharge occasional volumes of smoke, as in the case of the steam-engine, or perpetually give off more or less evil-smelling and poisonous vapours, as in the case of the oil or gas engine.

It is to be feared, however, that the disadvantages of electric traction or propulsion so greatly exceed the advantages derivable from its use, that except in certain very exceptional cases or where expense is of no importance, and perhaps to a very limited extent in some large towns and cities, this system must be considered impracticable. This fact is fully recognised and acknowledged by many electricians of note both in this country and abroad.

The following are examples of some of the most successful electrical road carriages that have been constructed up to the present time, from the designs of the American Electric Vehicle Company, Holtzer, Morris & Salom, Sturge, Bersey, Jeantaud, and Bogard.

American Electric Vehicle Company's Electric Road Carriage.

An electric storage battery carriage, constructed by the American Electric Vehicle Company, has been under trial for upwards of three months, and is said to have been found so successful that they are about to build a number of others of various patterns. That under consideration is a carriage of the mail phaeton type, weighing complete slightly under 18 cwt., and fitted

with a front seat, having a folding hood and an open rear seat.

The running gear of this carriage is clearly illustrated in Figs. 71 and 72. It is mounted upon four wheels, having ball bearings and solid indiarubber tyres, the front or steering wheels being 34 inches in diameter, the rear or driving wheels 44 inches in diameter, and the width of the wheel base being 4 feet 6 inches. The body of the vehicle contains storage

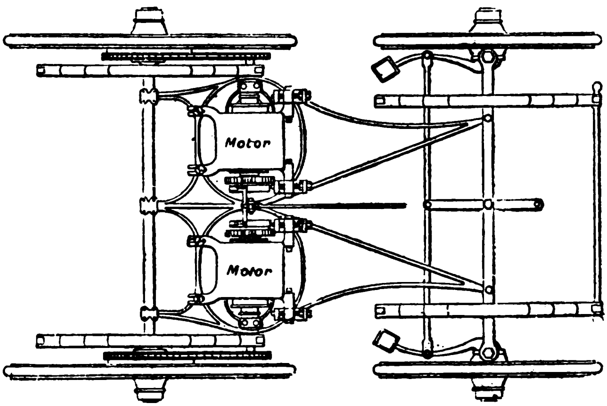


FIG. 71.—American Electric Vehicle Company's Electric Road Carriage (Plan of Mechanism).

room for a battery of thirty-two cells, having a capacity sufficient to develop 3½ horse-power for six hours, and so arranged that they need not be removed for charging. The carriage is capable of making 50 to 65 miles on one charge, in accordance with the state of the roads and the strength and direction of the wind. There are two motors, each of 1,200 watts or 1¾ horse-power, and independently connected to the rear or driving wheels by sprocket or chain wheels

and pitch chains, so as to admit of their running at different speeds when turning corners or rounding curves. Four different rates of speed are provided, viz., $1\frac{3}{4}$, $3\frac{1}{2}$, 7, and 14 miles per hour. A braking device is provided, whereby the brake can be applied directly to the motors, and this application will at the same time both cut off the electrical current from the said motors, and also automatically adjust the controller back to the starting-point.

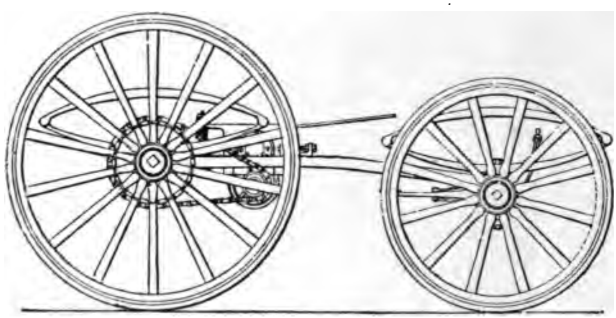


FIG. 72.—American Electric Vehicle Company's Electric Road Carriage (Side Elevation of Mechanism).

Holtzer's Electric Road Carriages.

The Holtzer electric storage battery carriage consists of a heavy drag, which weighs about 2 tons 5 cwt. 2 qrs., and is adapted to carry six or seven passengers. It is mounted upon four wheels having bearings of the ball variety. The storage batteries are located in the body of the vehicle and beneath the front seat, and that part of the body carrying the two rear seats is so hinged as to be capable of being lifted up, and thus exposing the cells and connections.

The batteries consist of 44 chloride cells of 250 ampère-hours, with a discharge rate of 25 ampères nominal, and arranged in four groups of eleven cells in each. These cells are connected to the motor through a parallel series controller, by which the groups are placed in multiple series and multiple gear respectively, so that three speeds can be obtained, viz., 5, 8, and 15 miles per hour. A lever placed near the steering pillar admits of these being operated and locked in either position by means of

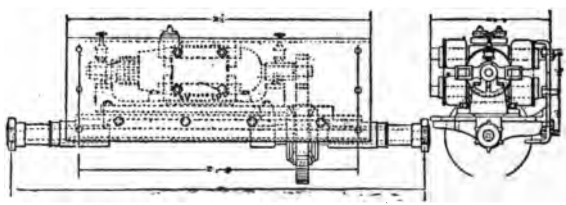


FIG. 73.—Holtzer's Electric Motor and Gear (Plan).

FIG. 74.—Holtzer's Electric Motor and Gear (End View).

a toothed sector and spring catch or pawl, and no rheostat is required in this arrangement.

The electric motor is a 4-pole series-wound one, of $7\frac{1}{2}$ horse-power capacity, weighing about 4 cwt., running at a full load at 250 revolutions per minute, and showing an efficiency, according to the makers, of 89 per cent.

The general arrangement of this motor is shown in plan and end view in Figs. 73 and 74. An armature pinion formed of phosphor bronze meshes with an accurate intermediate gear mounted upon a divided

shaft connected through a differential gearing, so as to admit of the wheels running at different speeds when rounding corners or running in curves. The rear wheels are driven from the intermediate shaft direct by chain gearing placed at each end, and to allow of reversing the direction of motion a reversing switch is mounted on the sector of the controller, and is interlocked therewith, thereby preventing the motor from being reversed until the controller lever has been placed at off.

The steering gear consists of a steering pillar coupled by strong levers to the movable hubs of the front axle. A toothed segment having a spring catch or pawl is also so arranged that by a slight pressure of the foot of the rider the front or steering wheels may be locked at any angle.

The motor and gearing are enclosed by a light leather casing, and the body of the carriage is waterproofed and painted with acid-proof paint to resist the action of acids should one of the cells become accidentally broken or slop over.

The carriage is provided with electric lamps of 10 candle-power each, and it was built by the Holtzer-Cabot Electric Company.

Morris & Salom's Electric Road Carriage.

The Morris & Salom storage battery carriage, which has been given by the designers the somewhat extraordinary name of the "Electrobat," is fitted with two Lundell electric motors of 1½ horse-power nominal each. The driving is effected by pinions upon the armature shafts operating the driving gears at-

tached to the front axle. The rear wheels are used for steering, and the steering pillar is arranged to shift the rear axle.

The supply of electricity is stored in four sets of twelve chloride cells, having a capacity of 50 ampère-hours per cell. The act of pushing into place makes connection automatically with the controller, which latter is operated by a hand wheel in front of the seat, four different speeds of travel being attainable by different groupings of the batteries with the motors. The capacity of this battery is said to be sufficient for a run of twenty hours, and a speed of 20 miles per hour to be attainable on good roads.

This carriage, which is adapted for the accommodation of two passengers, is mounted upon wooden wheels, the front or driving ones being 40 inches and the rear or steering ones 28 inches in diameter, and its weight is about 14 cwt. 1 qr. A lighter carriage of the same type of driving gear, but having a frame composed of steel tubes and cycle pattern wheels, and only weighing about 10 cwt. 3 qrs., is also made by the same builders.

Sturge's Electric Road Carriage.

The Sturge accumulator or storage battery electric carriage is of the three-seated sulky pattern, adapted to accommodate six passengers. It is mounted upon four wheels, the front ones being 42 inches and the rear ones 48 inches in diameter.

The motor is one of 3 horse-power, single reduction gear being employed for transmitting the power to the axle.

The body of the vehicle is capable of accommodating 36 storage battery cells, having a capacity of 250 ampère-hours, the power stored up therein being equal to 23 electrical horse-power. When, however, it is required to carry more batteries, so as to adapt the carriage for a lengthy run, the rearmost seat can be removed, thereby affording more storage capacity.

In running order this carriage weighs about 1 ton 4 cwt. 2 qrs. On good roads it is calculated to be capable of attaining a speed of 10 miles per hour, and to be able to cover a distance of 70 miles without requiring recharging.

Bersey's Electric Road Carriage.

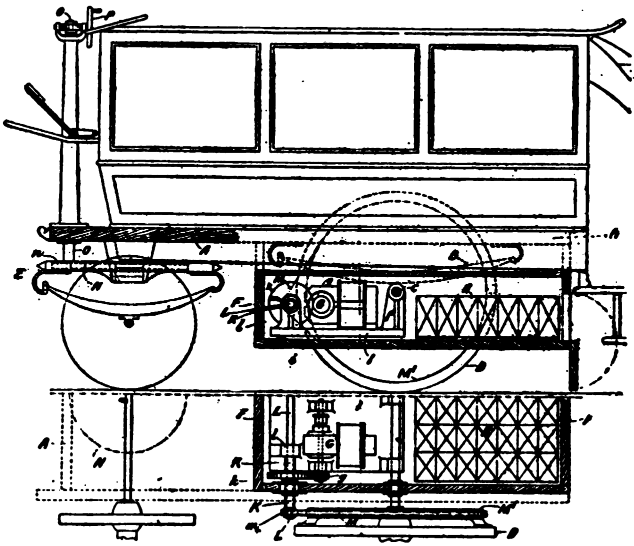
Figs. 75 and 76 illustrate an improved electrically propelled road vehicle or omnibus, designed by W. C. Bersey.

The improvements consist essentially in the interposition, between the vehicle body and the axles, of an under frame supported on springs on the fore carriage and the rear wheel axle, upon which under frame the accumulators, motors, driving and steering gear, brakes, and all the other appliances necessary for the electric propulsion of the vehicle are carried, so that it forms in itself a vehicle complete in every respect save the body. The body is seated directly on this under frame, which is especially adapted to receive it, and is merely dropped into position and fixed in place by means of bolts.

A is the horizontal under frame, which is supported through springs B on the axle C of the hind wheels D, and upon a swivelling fore carriage E. The omnibus

body is merely seated, as shown, on the frame A, its sills resting on and being bolted to the side members, and its floor or bottom upon the cross members of the frame A.

F is a downwardly projecting box or well carried by the frame A, in which well the motors G and ac-



FIGS. 75 and 76.—Bersey's Electric Omnibus (Sectional Side Elevation and Sectional Half Plan).

cumulators H are carried, the former being arranged in advance, and the latter in rear, of the hind wheel axle C, and the well having a door at the rear (shown open in the sectional elevation) through which the accumulators can be introduced.

The two motors G are carried upon the same base plate I, which is suspended by brackets I^1 at one end from the hind wheel axle C, the other end resting, through a roller *i*, on the floor of the well F. Upon the same base is mounted an intermediate stationary spindle L on which rotate sleeves K, through which the motors are geared to the respective driving wheels D, by a pinion *g* on the motor spindle, gearing with a wheel *k* on the said sleeve K. The stationary spindle L is fixed in brackets *l*, *l* on the base plate I; each end of the spindle, and the sleeve mounted thereon, passing out through the side walls of the well F, and the sleeve being provided with a sprocket pinion *m* gearing through a pitch chain M with a chain rim M^1 fixed to the wheel D. If a two-speed gear is required, two sets of wheels and pinions *g*, *k*, having different ratios, would be provided, the two wheels *k* being in that case mounted loosely on a live shaft with which one or other of said wheels is connected by an intermediate clutch.

The fore carriage E is unaltered from the ordinary pattern, except that its swivelling connection with the frame A is preferably made by means of a ball-bearing turning plate and centre bolt, the swivelling under carriage being provided with a toothed ring N with which gears a pinion *n* on the lower end of a vertical shaft O, passing up through a tubular standard fixed on the forward end of the frame A, and rising in front of the vehicle body to a convenient height to bring the hand wheel P and worm gear, through which the shaft O is operated, within easy reach from the driver's seat. The toothed ring N and pinion *n* are shown in dotted lines in the drawing.

Jeantaud's Electric Road Carriage.

A type of carriage propelled by an electric motor, which took part in the Paris-Bordeaux race, and by the aid of numerous relays succeeded in getting over half the course, although making far worse time than any of the petroleum cars, is that known as the Jeantaud car.

This vehicle is admirably designed for travelling, and had it not been so heavily handicapped by the source from which the energy was obtained, would doubtless have given very favourable results. The frame is constructed of weld steel, a box seat for two persons is placed in front, and two other seats placed back to back are located at the rear. It is mounted upon four wheels, the rear ones being 4 feet 7 inches in diameter and the front ones 3 feet 3 inches in diameter, and the load is proportionately distributed on both sets of wheels. Two straight springs connected together at their centres are supported upon the cross bearers close to their pivots, being placed on the under side transversely to the body which they support—an arrangement affording both great flexibility to the vehicle, and lessening the amount of force required for propulsion, inasmuch as when one of the wheels is raised over an obstacle, the entire weight of the said vehicle has not to be also raised.

An instantaneous brake, which can be operated by a pedal placed in a position convenient to the conductor and breaks the electrical circuit, is provided, as also a graduating brake which can be operated by two hand wheels, one of which is located at each side of the driver's box. A safety device is also fitted

which automatically acts to stop the car should the pitch or driving chains happen to break upon a gradient, a not altogether unlikely accident, by the way, and one which should be adequately provided against in all motor cars wherein the transmission of power is effected by chain gearing.

The intermediate shaft carries a differential gear comprising two bevel wheels admitting of speeds of 7½ and 15 miles, above the regular ones, being attained when desired. The intermediate shaft drives the wheels through chain or sprocket wheels and pitch chains.

The motor employed is from the designs of, and built by, Mr Rechniewski, having his usual grooved coil to afford protection to the wires and diminish the magnetic resistance, and it is intended to supply about 6 horse-power, which power, it is estimated, would be necessary to attain a speed of 15 miles an hour under normal conditions, with a tension of 70 volts with 70 ampères of current. The weight of the motor is about 5 cwt., and it is stated that upon special occasions it is capable of exerting sudden pulls and developing about double its stated power.

The electric current is supplied by accumulators consisting of 38 Fulmen elements placed in 12 boxes containing three and four compartments each. For a discharge of 70 ampères of current, the battery having a minimum capacity of 210 ampère-hours would be capable of working the vehicle for three hours at a speed of 15 miles per hour on a level road in first-rate condition. Each element has a 300 ampère-hour capacity for ten hours at a normal rate of discharge. The car may be taken under ordinary conditions to

be capable of running 25 miles on high-class roads, with no steep gradients, in favourable weather. As regards weight, each element weighs 33 lbs., the entire battery about 16¾ cwt., and the weight of the motor and fittings is about 7 cwt. About ten minutes would be consumed in recharging the storage battery.

Bogard's Electric Road Carriage.

In the Bogard electric car the motor is fixed to the framework, and operates an intermediate shaft, carrying chain or sprocket wheels at its extremities, through a pinion and differential gearing. Power is transmitted from this intermediate shaft to the rear or driving wheels, by means of pitch chains gearing with the above-mentioned sprocket wheels, and others fixed on the hubs of the said wheels.

The motor is also of the type made by Mr Rechniewski, with a grooved coil, to afford, as has been before mentioned, protection to the wires and diminish the magnetic resistance. A current of 14 ampères at 13 or 15 volts is delivered to the electros, and the coil at 90 volts is capable of absorbing up to 60 ampères, and will give out 6½ horse-power. At 88 volts the motor has a speed of 1,250 revolutions, at 44 volts one of 600 revolutions, and at 22 volts one of 300 revolutions. Fully charged, it gives 45 ampères, and an average of from 5 to 6 horse-power. The motor can be reversed when desired, and weighs a trifle over 4¼ cwt.

The accumulators employed are of the Dujardin type, and are placed in the body of the car, which is especially designed to afford ample accommodation

for their storage. The battery comprises 51 elements (each of three positive and four negative plates), each of which weighs with connections about 50 lbs. The total energy of this battery is 30 kilowatt-hours, which, it is estimated, would be sufficient to drive the car for ten hours at ordinary speed. It is divided into five groups, viz., a 7-element one for the excitation of the motor, and four of 11 elements in each, which can be connected in tension or in quantity in accordance with the speeds required. This latter arrangement enables the speed to be varied by altering the electromotive force through connecting up the above four groups in different manners.

This method of altering the rate of travel of the carriage, whilst greatly reducing the complication of the transmission mechanism, is obviously only suitable for use in cases where the vehicle is required to travel upon surfaces which are level or nearly so. The total weight of the car in working order is about 2 tons 3 cwt.

CHAPTER VI.

MISCELLANEOUS MOTOR CARS OR POWER-CARRIAGES.

AMONGST the miscellaneous sources of energy that might be utilised for the propulsion of motor cars may be mentioned hot and compressed air, carbonic acid, and springs. The first two of these are the only ones capable of anything like practical application.

Carbonic Acid Engines.

Carbonic acid gas, it is true, when compressed to a liquid contains a large store of energy, which can be regained when allowed to re-expand to a gaseous form. According to Sir Henry E. Roscoe, F.R.S., the vapour tension of carbon dioxide or carbonic acid (CO_2) at a temperature of 32° F. is 35.5 atmospheres, and at a temperature of 86° F. is 73.5 atmospheres. The great difficulties experienced, however, in applying the power that can be thus stored up to the piston of an engine are such as to render its successful practical application almost if not quite impossible. The poisonous nature, moreover, of carbonic acid or carbon dioxide gas (CO_2), although not so great as that of carbon monoxide or carbonic oxide gas (CO), the in-

halation of a minute quantity of which is sufficient to produce death, is still sufficiently dangerous, the presence of 0.10 per cent. (1 part per 1,000) being enough to render air unfit for continued respiration.

Spring Motors.

The last method mentioned, or the storing up of force in springs, a source of energy acting so admirably for supplying the requisite motive power for watches, clocks, and other small mechanisms, is ill adapted for use where the development of any considerable amount of power is required. This results from two causes—first, the difficulty of obtaining suitable springs for the purpose; and secondly, the still greater objection occasioned by the large power that has to be expended to compress such springs, and so store up sufficient energy for any lengthened effort due to their reaction.

Compressed Air Engines.

Under the above circumstances, and in view of the absence of any practical motors of the two latter descriptions, it would seem idle to go further into the matter, nor indeed is the second source of energy mentioned or compressed air much more suitable for use in the case of motor cars or power carriages for common roads, although it may be used with some measure of success for working cars on lines of rail where means for the supply of air under suitable pressure are located at terminal stations, and elsewhere where necessary, at proper points along the lines.

The originator of the use of compressed air as a means of transmitting power is generally acknowledged to be that most ingenious Frenchman, Dr Papin, whose name is so familiar in connection with the steam-engine. His experiments, however, which dated about 1700, were abortive, owing to the inferior appliances then available.

Compressed air is utilised to drive a compressed air engine, that is, an engine the piston whereof is driven by the elastic force of the said compressed air, and the construction of such an engine does not differ materially from that of a steam-engine wherein steam under pressure is used for a like purpose. In applying this system to a motor car two methods may be adopted, viz., first, the storage in a suitable reservoir of a sufficient supply of air under high tension to drive the compressed air engine, and therefore the car, for a specified distance under normal conditions, after which the said reservoir will require recharging; and second, the compression of the air upon the car itself by means of an internal combustion engine and small air pump or compressor.

Locomotives have long been constructed which are adapted to be driven by means of air compressed into reservoirs. That of Bompas of 1828 had two tanks which were charged with air under pressure by stationary engines at the depots and way stations. The engine employed was practically similar to that of a steam-engine, the air being admitted from each of the reservoirs alternately to the opposite sides of the pistons working in the cylinders to which the said reservoirs were respectively connected.

An engine practically identical in construction to

the above was built by Baron von Rathlen in 1848 and was successfully run from Putney to Wandsworth, attaining a speed of from 10 to 12 miles an hour.

A year previously also (1847) a locomotive engine of this type was designed by Parsey, which comprised a reservoir wherein the air was compressed to as high a tension as could be done with safety, and from which it was gradually and automatically discharged into a second reservoir or chamber wherein it was permitted to expand to the predetermined working pressure, and from which it was withdrawn for use in the cylinder of the compressed air engine in the usual manner.

Compressed air has been, and is, used with some success for the propulsion of street cars. Notably in this direction mention may be made of the Popp-Conti and Méharski systems, descriptions of which, however, we are unable to give, as the scope of this little work is confined to such power-propelled carriages as are adapted to travel upon the surfaces of common roads, and does not therefore extend to tram-cars.

The compression of the air upon the car itself, which plan has been suggested for use on motor cars for running upon common roads, would of course necessitate the provision of an oil motor or other internal combustion engine, or of some other source of energy to compress the said air. In the case of an internal combustion engine an advantage would be derived in the possibility of reversing the compressed air engine with ease at will, and likewise in the greater facility and range of regulation of speed that could be

effected. Another advantage would also be gained from the fact that the running of the said combustion engine, during any temporary stoppages of the car, could be utilised to get up a store of compressed air in a reservoir, and would not be so much wasted energy, as is the case at present. Were a steam-engine, however, to be employed to compress the air, there would be no such compensating features to place against the obvious losses that would be experienced in both cases by reason of increased friction, leakage, additional complication of parts, and added weight of mechanism. Possibly a hot-air or caloric engine might be successfully combined with an air compressor and compressed air engine for working light motor cars.

The compressing of the air necessary to work a compressed air engine directly upon the motor car itself would not only do away with the necessity of carrying a cumbersome and weighty reservoir, but would, which is perhaps more important, also render the vehicle independent of extraneous aid for a renewal of the supply. For a like reason it has, as already mentioned, been proposed to do away with the heavy storage battery required to supply the necessary current of electricity to drive the electric motor, and to employ upon the motor car itself an internal combustion engine and dynamo to generate such current. The advantages derivable in this case would include the facility of stopping, starting, and reversal of the electric motor, great reduction of dead load, and if a small storage battery or accumulator was also provided, the utilisation of the running of the combustion engine during temporary stoppages of the car to store up a supply of electricity for emergencies. The same

objections, however, could also be urged against this plan as those mentioned with regard to the former one.

Hot-Air or Caloric Engines.

Hot-air engines possess many advantages for the purpose of propelling vehicles on common roads, inasmuch as they combine some of the good qualities of both steam, oil, and electricity.

Hot-air or caloric engines, which are driven by the heating of a body of air admitted to the cylinder, may be broadly divided into two principal or main classes, viz., those taking their supply direct from the atmosphere, and discharging the same again into the atmosphere after use; and those wherein the same air is continually employed in a closed cycle, being alternately heated and cooled but not allowed to escape. The first class is exemplified in the well-known Ericsson engine, and the second in that of Parkinson & Crossley.

This type of motor, *i.e.*, the caloric or hot-air engine, may, however, be conveniently further subdivided as follows:—

First. Those engines which compress the air into a reservoir, from which it is discharged in graduated amounts, heated, used to drive a piston, and subsequently discharged. This forms a very numerous class, and two systems of working are used, one in which the air is passed through the furnace, and the other in which the air is merely heated without passing it into or through the furnace.

Second. Those engines in which the same air is

brought again and again to the heater, its temperature raised to a suitable point, and expanded.

Third. Those engines wherein two reservoirs or chambers are employed, one of which is in communication with each end of the cylinder, and therefore with opposite sides of the piston, and the air in which reservoirs or chambers is alternately heated and cooled and utilised without being expended or allowed to escape into the atmosphere.

Fourth. Those engines wherein the air is moistened by means of water or steam, so as to lubricate the rubbing surfaces, which class are commonly known as aëro-steam-engines. And

Fifth. Those engines in which a body of water is interposed between the power derived, to prevent burning of the working parts, and also to facilitate the maintenance of tight joints.

This burning of the working parts and necessity for the excessive consumption of lubricants, and the difficulty of maintaining air-tight joints, form indeed the chief difficulties to be overcome with regard to the successful working of caloric engines.

A caloric engine especially suitable for motor-car work has yet to be designed, and it seems to the author that inventors would find this a paying field in which to utilise their inventive genius.

APPENDIX A.

SUMMARY OF PROVISIONS OF ACTS OF PARLIAMENT.

LOCOMOTIVES ON PUBLIC HIGHWAYS.

LOCOMOTIVES, propelled by steam, passing along public highways, must (unless they come within the provisions of the Act of 1896: see next heading) be worked according to the subjoined rules (24 & 25 Vict. c. 70; 28 & 29 Vict. c. 83; 41 & 42 Vict. c. 77):—

1. At least three persons must be employed to drive or conduct such locomotive: and if more than two waggons are attached, then an additional person.

2. One of such persons, while the locomotive is in motion, shall precede, by at least 20 yards, the locomotive on foot, and shall in case of need assist horses and carriages drawn by horses passing the same.

3. The drivers of such locomotives must give as much space as possible for the passing of other traffic.

4. The whistle of the locomotive must not be sounded for any purpose whatever; nor the cylinder taps opened within sight of any person riding, driving, or leading a horse upon the road; nor shall the steam be allowed to blow off upon the road.

5. The locomotive must be instantly stopped on signal being given, either by the attendant in front, or by any person with a horse, or with a carriage drawn by a horse.

6. The locomotive must be provided with two efficient front lights when passing along the road at night, between one hour after sunset and one hour before sunrise.

The speed on the roads is not to exceed 4 miles an hour, or when passing through towns and villages 2 miles.

Penalty on infringement of rules, £10 on summary conviction, to be recovered of the owner, who may recover back the amount from the attendant in default. The name and residence of the owner must be conspicuously affixed to the locomotive. Maximum penalty £2 for default.

A locomotive used on highways must be constructed so as to consume its own smoke. Fine, in default, £5 per day.

Light Locomotives (Auto-Cars or Motor-Cars) Act, 1896.

The Act of 1896, which came into operation on 14th November 1896, provides that existing enactments restricting the use of locomotives on highways (including the enactments cited above) shall not apply to any vehicle propelled by mechanical power if it is under 3 tons in weight unladen, and is not used for the purpose of drawing more than one vehicle (such vehicle with its locomotive not to exceed in weight unladen 4 tons), and is so constructed that no smoke or visible vapour is emitted therefrom except from any temporary or accidental cause; and vehicles so exempted, whether locomotives, or drawn by locomotives, are classed as "light locomotives" (sec. 1).

The council of any county or county borough may make bye-laws preventing or restricting the use of such locomotives upon bridges within their area; and a "light locomotive" is to be deemed to be a carriage within the meaning of

existing Acts or bye-laws, and, if used as a carriage of any particular class, is to be deemed a carriage of that class (sec. 1).

In calculating the weight of a vehicle unladen, the weight of water, fuel, or accumulators used for the purpose of propulsion shall not be included (sec. 1).

During the period between one hour after sunset and one hour before sunrise, the person in charge of a light locomotive shall carry attached thereto a lamp so constructed and placed as to exhibit a light in accordance with regulations of the Local Government Board; every light locomotive shall carry a bell or other instrument capable of giving audible and sufficient warning of the approach or position of the carriage; and no light locomotive shall travel along a public highway at a greater speed than 14 miles an hour or any less speed prescribed by regulations of the Local Government Board (secs. 2, 3, 4).

The keeping and use of petroleum, or of any other inflammable liquid or fuel for the purpose of light locomotives, shall be subject to regulations made by a Secretary of State (sec. 5).

The regulations to be made by the Local Government Board may cover the use of light locomotives on highways, their construction, and the conditions under which they may be used, and any breach of a bye-law or regulation under the Act, or of any provision of the Act, may, on summary conviction, be punished by a fine not exceeding £10 (secs. 6, 7).

APPENDIX B.

LOCAL GOVERNMENT BOARD REGULATIONS.

UNDER the provisions of the Act of 1896 (referred to in Appendix A.), the Local Government Board have issued the following regulations, taking effect as from 14th November 1896:—

ARTICLE I.

In this Order:—

The expression "carriage" includes a waggon, cart, or other vehicle.

The expression "horse" includes a mule or other beast of draught or burden, and the expression "cattle" includes sheep.

The expression "light locomotive" means a vehicle propelled by mechanical power which is under 3 tons in weight unladen, and is not used for the purpose of drawing more than one vehicle (such vehicle with its locomotive not exceeding in weight unladen 4 tons), and is so constructed that no smoke or visible vapour is emitted therefrom, except from any temporary or accidental cause.

In calculating for the purposes of this Order the weight of a vehicle unladen, the weight of any water, fuel, or accumulators used for the purpose of propulsion shall not be included.

ARTICLE II.

No person shall cause or permit a locomotive to be used on any highway, or shall drive or have charge of a light locomotive when so used, unless the conditions hereinafter set forth shall be satisfied, namely:—

1. The light locomotive, if it exceeds in weight unladen

5 cwt., shall be capable of being so worked that it may travel either forwards or backwards.

2. The light locomotive shall not exceed 6½ feet in width, such width to be measured between its extreme projecting points.

3. The tyre of each wheel of the light locomotive shall be smooth, and shall, where the same touches the ground, be flat and of the width following, namely:—(*a*) If the weight of the light locomotive unladen exceeds 15 cwt. but does not exceed 1 ton, not less than 2½ inches; (*b*) if such weight exceeds 1 ton but does not exceed 2 tons, not less than 3 inches; (*c*) if such weight exceeds 2 tons, not less than 4 inches.

Provided that where a pneumatic tyre, or other tyre of a soft and elastic material is used, the tyre may be round or curved, and there may be upon the same projections or bosses rising above the surface of the tyre, if such projections or bosses are of the same material as that of the tyre itself, or of some other soft and elastic material. The width of the tyre shall, for the purpose of this proviso, mean the extreme width of the soft and elastic material on the rim of the wheel when not subject to pressure.

4. The light locomotive shall have two independent brakes in good working order, and of such efficiency that the application of either to such locomotive shall cause two of its wheels on the same axle to be so held that the wheels shall be effectually prevented from revolving, or shall have the same effect in stopping the light locomotive as if such wheels were so held. Provided that, in the case of a bicycle, this regulation shall apply as if, instead of two wheels on the same axle, one wheel was therein referred to.

5. The light locomotive shall be so constructed as to admit of its being at all times under such control as not to cause undue interference with passenger or other traffic on any highway.

6. In the case of a light locomotive drawing or constructed to draw another vehicle or constructed or used for the carriage of goods, the name of the owner and the place of his abode or business, and in every such case and in the case of every light locomotive weighing unladen 1½ ton or upwards, the weight of the light locomotive unladen shall be painted in one or more straight lines upon some conspicuous part of the right or off side of the light locomotive in large legible letters in white upon black or black upon white, not less than 1 inch in height.

7. The light locomotive and all the fittings thereof shall be in such a condition as not to cause, or to be likely to cause, danger to any person on the light locomotive or on any highway.

8. There shall be in charge of the light locomotive when used on any highway a person competent to control and direct its use and movement.

9. The lamp to be carried attached to the light locomotive in pursuance of section 2 of the Act shall be so constructed and placed as to exhibit, during the period between one hour after sunset and one hour before sunrise, a white light visible within a reasonable distance in the direction towards which the light locomotive is proceeding or is intended to proceed, and to exhibit a red light so visible in the reverse direction. The lamp shall be placed on the extreme right or off side of the light locomotive in such a position as to be free from all obstruction to the light.

Provided that this Regulation shall not extend to any bicycle, tricycle, or other machine to which section 85 of the Local Government Act, 1888, applies.

ARTICLE III.

No person shall cause or permit a light locomotive to be used on any highway for the purpose of drawing any vehicle,

or shall drive or have charge of a light locomotive when used for such purpose, unless the conditions hereinafter set forth shall be satisfied, namely:—

1. Regulations 2, 3, 5, and 7 of Article II. of this Order shall apply as if the vehicle drawn by the light locomotive was therein referred to, instead of the light locomotive itself, and Regulation 6 of the Article shall apply as if such vehicle was a light locomotive constructed for the carriage of goods.

2. The vehicle drawn by the light locomotive, except where the light locomotive travels at a rate not exceeding 4 miles an hour, shall have a brake in good working order of such efficiency that its application to the vehicle shall cause two of the wheels of the vehicle on the same axle to be so held that the wheels shall be effectually prevented from revolving, or shall have the same effect in stopping the vehicle as if such wheels were so held.

3. The vehicle drawn by the light locomotive shall, when under the last preceding Regulation a brake is required to be attached thereto, carry upon the vehicle a person competent to apply efficiently the brake: Provided that it shall not be necessary to comply with this Regulation if the brakes upon the light locomotive by which the vehicle is drawn are so constructed and arranged that neither of such brakes can be used without bringing into action simultaneously the brake attached to the vehicle drawn, or if the brake of the vehicle drawn can be applied from the light locomotive independently of the brakes of the latter.

Article IV.

Every person driving or in charge of a light locomotive when used on any highway shall comply with the Regulations hereinafter set forth, namely:—

1. He shall not drive the light locomotive at any speed

greater than is reasonable and proper, having regard to the traffic on the highway, or so as to endanger the life or limb of any person, or to the common danger of passengers.

2. He shall not under any circumstances drive the light locomotive at a greater speed than 12 miles an hour. If the weight unladen of the light locomotive is $1\frac{1}{2}$ ton and does not exceed 2 tons, he shall not drive the same at a greater speed than 8 miles an hour, or if such weight exceeds 2 tons, at a greater speed than 5 miles an hour.

Provided that whatever may be the weight of the light locomotive, if it is used on any highway to draw any vehicle, he shall not, under any circumstances, drive it at a greater speed than 6 miles an hour.

Provided also that this Regulation shall only have effect during six months from the date of this Order, and thereafter until we otherwise direct.

3. He shall not cause the light locomotive to travel backwards for a greater distance or time than may be requisite for purposes of safety.

4. He shall not negligently or wilfully cause any hurt or damage to any person, carriage, horse, or cattle, or to any goods conveyed in any carriage on any highway, or, when on the light locomotive, be in such a position that he cannot have control over the same, or quit the light locomotive without having taken due precautions against its being started in his absence, or allow the light locomotive or vehicle drawn thereby to stand on such highway so as to cause any unnecessary obstruction thereof.

5. He shall, when meeting any carriage, horse, or cattle keep the light locomotive on the left or near side of the road, and when passing any carriage, horse, or cattle proceeding in the same direction keep the light locomotive on the right or off side of the same.

6. He shall not negligently or wilfully prevent, hinder, or interrupt the free passage of any person, carriage, horse,

or cattle on any highway, and shall keep the light locomotive and any vehicle drawn thereby on the left or near side of the road for the purpose of allowing such passage.

7. He shall, whenever necessary, by sounding the bell or other instrument required by section 3 of the Act, give audible and sufficient warning of the approach or position of the light locomotive.

8. He shall, on the request of any police constable, or of any person having charge of a restive horse, or on any such constable or person putting up his hand as a signal for that purpose, cause the light locomotive to stop and to remain stationary so long as may be reasonably necessary.

ARTICLE V.

If the light locomotive is one to which Regulation 6 of Article II. applies, and the particulars required by that Regulation are not duly painted thereon, or if the light locomotive is one to which that Regulation does not apply, the person driving or in charge thereof shall, on the request of any constable, or on the reasonable request of any other person, truly state his name and place of abode, and the name of the owner, and the place of his abode or business.

APPENDIX C.

THE CARRIAGE OF PETROLEUM.

In promulgating the following regulations relating to the keeping, conveyance, and use of petroleum in connection with light locomotives, the Secretary of State for the Home Department desires to call public attention to the dangers that may arise from the careless use of those more volatile descriptions of petroleum to which these rules apply, being petroleum to which the Petroleum Act, 1871, applies, and commonly known as "mineral spirit."

Not only is the vapour therefrom, which is given off at ordinary temperature, capable of being easily ignited, but also, when mixed with air, of forming an explosive mixture. Hence the necessity for strict precautions in dealing with and handling the same, and for the employment of thoroughly sound and properly closed vessels to contain the same, the importance of avoiding the use of naked lights in dangerous proximity to the same or to any place where such petroleum may be kept, and generally of taking precautions to prevent contact of the highly inflammable vapour of this very volatile liquid with any form of artificial light.

Regulations.

1. Petroleum shall not be kept, used, or conveyed, except in tanks or cases of metal so made and closed that no

leakage, whether of liquid or vapour, can take place therefrom, and so substantially constructed as not to be liable, except under circumstances of gross negligence or extraordinary accident, to be broken or become defective or insecure in course of conveyance or use; and every air-inlet in any such tank or case shall be at all times, except when the valve, if any, is required to be removed for immediate use or repair, protected by securely affixed wire gauze, the openings in which shall not be less in number than 400 to the square inch.

2. Every such tank or case shall be clearly stamped or securely labelled with a legible metallic or enamelled label with the words "mineral spirit, highly inflammable, for use with light locomotives."

3. The amount of petroleum to be in any one such tank or case at one time shall not exceed 20 gallons.

4. There shall not be at the same time on or in any one light locomotive, more than two of such tanks as aforesaid.

5. Before repairs are done to any such tank or case, that tank or case shall, as far as practicable, be cleaned by the removal of all petroleum and of all dangerous vapours derived from the same.

6. When petroleum for use in, or in connection with any light locomotive is not being so used, it shall be kept either in accordance with the provisions of the Petroleum Acts, or in such tanks or cases as aforesaid; provided that the amount of petroleum which may be so kept in tanks or cases as aforesaid shall not exceed the amount of petroleum which may be kept on or in any one light locomotive at the same time, and that the tanks or cases shall be kept in the open air, or in some suitably ventilated place.

7. The filling or replenishing of a tank with petroleum shall not be carried on, nor shall the contents of any such tank be exposed by artificial light, except a light of such construction, position, or character as not to be liable to

cause danger, and no artificial light shall be brought within dangerous proximity of the place where any tank containing petroleum is being kept.

8. In the case of all petroleum kept or conveyed for the purpose of or in connection with any light locomotive (*a*) all due precautions shall be taken for the prevention of accidents by fire or explosion, and for the prevention of unauthorised persons having access to any petroleum kept or conveyed, and to the vessels containing or intended to contain, or having actually contained the same; and (*b*) every person managing or employed on or in connection with any light locomotive shall abstain from every act whatever which tends to cause fire or explosion, and which is not reasonably necessary, and shall prevent any other person from committing such act.

9. These regulations shall come into operation on the 14th day of November 1896, and be in force until further notice.

APPENDIX D.

TAXES ON MOTOR CARRIAGES.

RULES COMING INTO FORCE ON 1ST JANUARY 1897.

ALL motor cars or power-propelled vehicles weighing less than 1 ton, £1 1s. or 15s. a year, in accordance to whether they are used for private purposes or as public conveyances. Motor cars above 3 tons in weight will be subject to the same tax. With four or more wheels, weighing between 1 and 2 tons, £4 4s. a year if used for private purposes; if for hackney carriages or omnibuses, £2 17s. Over 2 and under 3 tons, £5 5s. and £3 18s. respectively. Cars of this class, with less than four wheels, between 1 and 2 tons, £2 17s., whether used as private or public conveyances; and if weighing over 2 and under 3 tons, £3 18s.

In case of a car not being used for the first time until 1st October in any year, a reduction of £1 1s. if for private, and of 7s. 6d. if for public, use will be made.

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